한국기계가공학회지, 제17권, 제5호, pp.45～51(2018.10) ISSN 1598-6721(Print)
Journal of the Korean Society of Manufacturing Process Engineers, Vol. 17, No. 5, pp.45~51(2018.10) ISSN 2288-0771(Online)

https://doi.org/10.14775/ksmpe.2018.17.5.045

Smart Roll Forming Based on Real-Time Process Data

Jae-Hwan Son[*], Dong-Hyun Cho[**,#], Chul-Hong Kim[***]
[*]DMI, [**]School of Mechanical Engineering, DAEJIN UNIV., [***]HANDOCK HI_TECH Co. LTD.

실시간 공정데이이터 기반의 스마트 롤포밍에 관한 연구

손재환[*], 조동현[**,#], 김철홍[***]
[*]대구기계부품연구원, [**]대진대학교 컴퓨터응용기계공학과, [***](주)한독하이테크
(Received 2 September 2018; received in revised from 6 September 2018; accepted 21 September 2018)

ABSTRACT

Roll forming refers to the production of long plate-molded products, such as panels, pipes, tubes, channels, and frames, by continuously causing the bending deformation to thin plates using rotating rolls. As the roll forming method has advantages in terms of mass production because of its excellent productivity, the size of the roll forming industry has been continuously increasing and the roll forming method is increasingly being used in diverse industrial fields as a very important processing method. Furthermore, as the roll forming method mainly depends on the continuous bending deformation of the plate materials, the time and the cost of the heterogeneous materials developed in the process are relatively large when considered from the viewpoint of plastic working because many processes are continuously implemented. The existing studies on roll forming manufacturing have reported the loss of large amounts of time and materials when the raw materials or product types were changed; further, they have stated that the use of this method can hardly guarantee the uniformity of the formed shapes and the consistency in terms of size and cannot detect all the defects occurring during the mass production and related to the dimensions. Therefore, in this research, a real-time process data-based smart roll forming method that can be applied to multiple products was studied. As a result, a roll forming system was implemented that remembers and automatically sets the changes in the finely adjusted values of the supplied quantities of individual heterogeneous materials so that the equipment setting changing time for heterogeneous material replacements or changes in the products being produced can be shortened. It also secures the uniformity of the products so that more competitive and precise slide-rail products can be mass-produced with improvements in the quality, price, and productivity of the products.

Keywords : Roll forming(롤 포밍), Real Time(실시간), Process Data(공정 데이터), Smart(스마트)

1. Introduction

Products such as slide rails, shape steel, channels, angles, and welded pipes are manufactured through steel plate roll forming processes. Roll forming manufacturing processes refer to continuously causing bending deformation to a thin plate using a rotating roll to manufacture long formed plate products such as panels, pipes, tubes, channels, and frames.[1,2] Since roll forming methods have advantages in terms of mass production as their

Corresponding Author : chodh@daejin.ac.kr
Tel: +82-31-539-1973, Fax: +82-31-539-1970

productivity is excellent, the scale of the roll forming industry has been continuously growing and roll forming methods are used as very important processing methods in diverse areas of the industry.[3] Although roll forming methods are relatively simple when seen from the viewpoint of plastic working because they mainly rely on continuous bending deformation of steel plates, relatively large amounts of time and costs are required for dissimilar materials for which processes have been developed because many processes are continuously implemented.[4] On reviewing the domestic and foreign study trends and technological levels of the steel plate roll forming technologies as such, it can be seen that although roll forming processes are plastic working methods the most suitable for precisely formed linear materials with constant lengthwise cross-sections, they require large amounts of equipment manufacturing and maintenance costs because the scales of equipment that must be installed are very large. In addition, cold-rolled steel plate coil(skelp) materials first have thickness variations of approximately ±0.02 ㎜from the standard nominal thickness even in lot units and show thickness variations of ±0.02 ㎜between the center and the edges when they are 1,260 ㎜wide intact coils before the slitting process and also show thickness variations of ±0.02 ㎜between the beginning and ending regions of each coil.[5,6] These variations appear as changes in shape dimensions in the form of waves in forming equipment with rollers fixed to a certain amount of reduction.[7] The quality of products has been controlled relying on the sense of workers by combining formed products randomly sampled per a certain quantity with counterparts sliding them.[8,9] However, this quality control is inefficient and the resultant product quality is not always constant. In addition, on reviewing the study trend for ball slide rails, it can be seen that ball slide rails are generally produced by obtaining raw plates with certain shapes and lengths from materials such as stainless coils, cold rolled plates (CR), or electronic galvanized sheet steel (EGI) through multi-stage continuous roll forming processing and finishing the raw plates with press processes. In the case of the roll forming equipment operation method as such, the losses of large amounts of time and materials are inevitable when raw materials or product types are changed, the constancy of formed shapes and dimensional quality cannot be easily secured, and defects made during mass production cannot be fully checked.[10] Although studies are conducted for the construction of dedicated lines by product with fixed setting for the foregoing reasons, in reality, the construction of individual dedicated lines by type of dissimilar materials is very difficult because of excessive equipment costs.[11-14] Therefore, in the present study, a system will be implemented that can remember the finely adjusted values of the amounts or reduction by type of dissimilar materials of forming equipment applicable to multiple products and can measure and monitor the dimensions of products formed during mass production in real time so that the time to change equipment setting for replacement of dissimilar materials for changes in products being produced can be shortened and the constancy of products can be secured leading to the enhancement of quality, prices, and productivity, which will enable the mass production of more competitive precise slide rail products.

2. Configuration and interpretation of real time smart roll forming system

Fig. 1 shows a dissimilar material roll forming system consisting of 12 top and bottom joining roller assemblies instead of the side roller forming method that has been a cause of frequent damage and poor formation in real time smart roll forming flows for single materials. Fig. 2 shows a diagram of the real time smart roll forming stage and the section design.

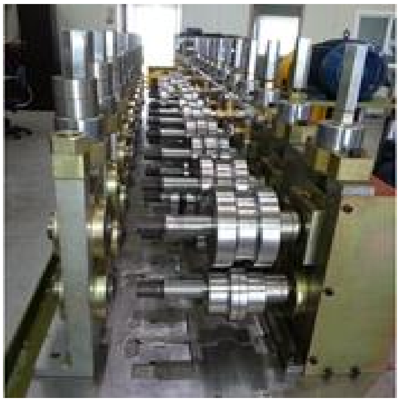

Fig. 1 Dissimilar material forming roll system

Fig. 2 A diagram of the real time smart roll forming stage and the section design

A common roll flow design for dissimilar materials was configured and plastic analysis simulations for individual materials were conducted to derive the strain rates of the roller tools at individual stages thereby effectively distributing the processes in the overload (concentrated load) stage in order to obtain the dual effects of the enhancement of precision and the improvement of roller life spans.

Fig. 3 and 4 show the mechanisms of the process of nonlinear analysis of Deform-2D. Since roll forming shows nonlinear behavior (plastic deformation, contact), the time should be divided to solve the nonlinear problems and time division is a very important element in the analysis. The type of problems that can be solved through 2D analysis has axial symmetry and plane strain rate conditions.

The deformation in the rotating direction was assumed to be constant with regard to the axial symmetry and the strain rate in the width direction was considered to be 0 with regard to the plane strain rate to conduct analyses using 2D-deform as an analysis program. Table 1 shows the mechanical property values of SPCC 1/4H BRIGHT necessary for analyses. The type of material applied to the roll analysis is SPCC 1/4H BRIGHT, which is thinner and has higher precision of dimensions, clearer and more beautiful surfaces, and more excellent flatness compared to hot-rolled steel plates. SPCC 1/4H BRIGHT is generally used for simple processing and is the most economic general steel plates.

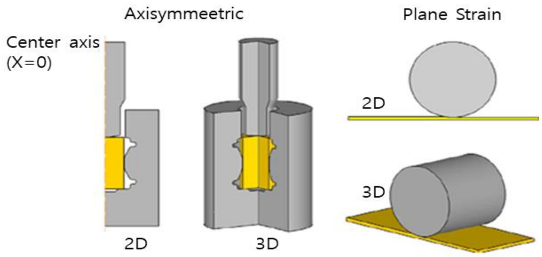

Fig. 3 Block diagram of nonlinear analysis of 3D shapes

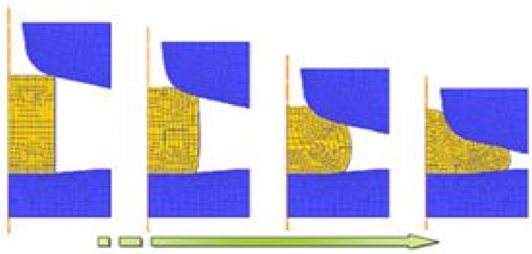

Fig. 4 Process of nonlinear analysis by Deform-2D

Table 1 Mechanical properties of SPCC 1/4H BRIGHT

Parts	Value	Unit
Young's Module	215	GPa
Poisson ratio	0.29	-
Yield Stress	240	N/㎟

Table 2 Roll forming analysis conditions

Analysis condition	Major factors
Roll forming material	KS D 3512 SPCC 1/4H BRIGHT
Coefficient of friction	0.12
Roll clearance	1.5 mm

Table 2 shows the roll forming analysis conditions. The roll forming analyses were conducted for two different processes; single material processes and the developed process for dissimilar materials to calculate plane strain rates. The clearance between the upper roll and the lower roll was set based on the material thickness 1.5 mm. Given that the roll clearance is the same as the material thickness, the analysis conditions were set considering only the bending deformation in the width direction without considering the deformation of the material in the length direction. The coefficient of friction was set to the default value of general cold forming.

With regard to the roll forming analysis, strips were formed through the roll forming machine and the strain rate was calculated in the profile after the strips passed the final roll stand. This process was repeated to form the shapes of the cross sections of the entire rolls. The amounts of deformation of the rolls obtained by 1/2 analysis because the rolls are symmetric in shape. As shown in Figure 5, fixing conditions were entered in the X, Y directions as boundary conditions and load interpolation conditions were set for places where the material is processed when roll forming is implemented.The single material roll forming processes were analyzed continuously from process 1 to process 11. The total number of rolls was 11 pairs. The work was repeatedly performed to form the shapes of the cross sections of the entire rolls. The roll forming processes for actual processing consist of eight processes.

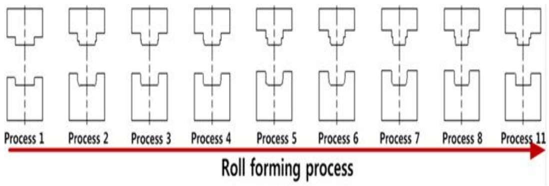

Fig. 5 Single material design roll forming process analysis process

Fig. 6 shows the process of analysis of dissimilar material design real time smart roll forming processes. The dissimilar material roll forming processes were continuously analyzed from process 1 to process 12. Strips were formed through the roll forming machine and the strain rate was calculated in the profile after the strips passed the final roll stand. The total number of rolls was 12 pairs. This process was repeated to form the shapes of the cross sections of the entire rolls to conduct analyses.

3. Results and discussion

3.1 Analysis results for roll forming materials

With regard to the strain rates of roll forming materials for single material roll forming designs, as shown in Fig. 7, the final strain rate in the bent region was shown to be 2.71 mm/mm and the strain rates in the bent region in each process were generally shown to be in a range of 0.2~0.25 mm/mm.

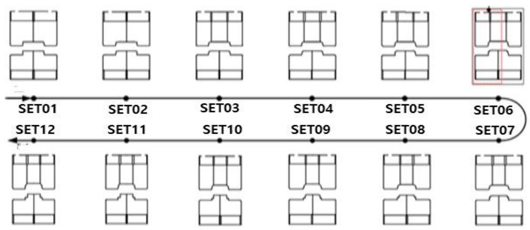

Fig. 6 Dissimilar material design smart roll forming process analysis process

The largest amount of deformation of the material was shown in process 2. With regard to the strain rates of roll forming materials for dissimilar material roll forming designs, as shown in Fig. 8, the strain rate at the area when bending started was shown to be 2.14 mm/mm and the variations in strain rates in the processes were generally improved considerably compared to the single material process.

3.2 Analysis results for roll forming roll

Fig. 9 shows the amount of deformation of the roll forming roll for a single material. Figure 10 shows the amount of deformation of roll forming roll for dissimilar materials. The deformation rate of the roll was found to be the highest at 0.005 mm / mm or higher in the bending part of the single material roll forming in general and this is considered attributable to the fact that the material was deformed the most in the relevant part leading to increases in the surface pressure on the roll. Based on these results, it is considered that whereas the deviation of the deformation rate is large during the roll-forming of a single material because the surface pressure on the roll is irregular, rolls are

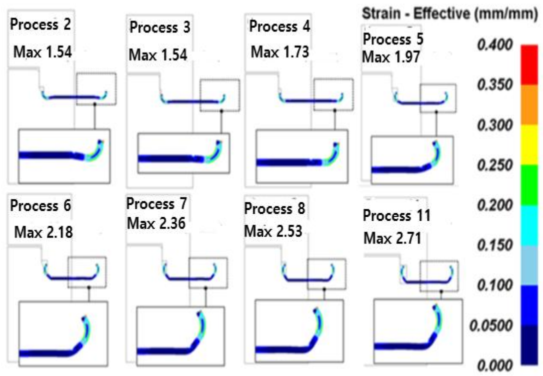

Fig. 7 The amounts of deformation of roll forming materials for single material designs

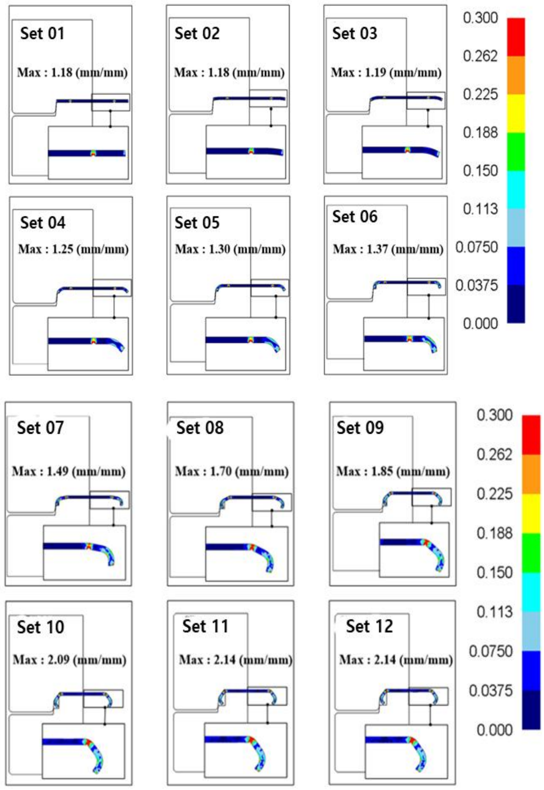

Fig. 8 The amounts of deformation of real time smart roll forming materials for dissimilar material designs

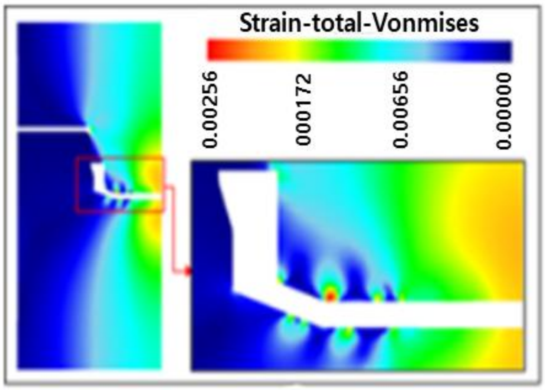

Fig. 9 Singlematerial deformation of the roll forming roll

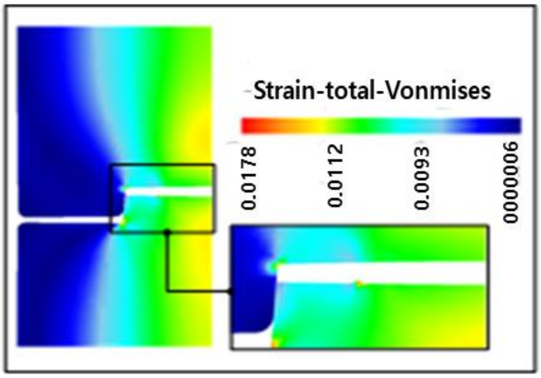

Fig. 10 Heterogeneous material deformation of the roll forming roll

formed more stably in the case of the roll forming process of dissimilar materials thanks to the regular surface pressure.

3.3 Experimental results

Fig. 11 shows the dimensional accuracy of the roll forming rail. As a reliability test method for the performance evaluation of the roll forming system, the roll forming measurement region of the guide rail, which is a sample to be tested, was divided into three equal parts, and the width dimensional accuracy of each part was measured 10 times to evaluate the Cp (Process Capability). The quality process capability is expressed by the standard deviation of the product produced by working according to the specified work standard from the defined work standard, and it is compared with the required conditions (tolerance, tolerance limit) to identify the degree of satisfaction of the process capability. It is obtained as shown in the following equation and the criterion for judgment of quality process capability is as shown in equation (1).

$$C_p = \frac{SU-SL}{6S} \tag{1}$$

Each sample was measured 10 times to evaluate the

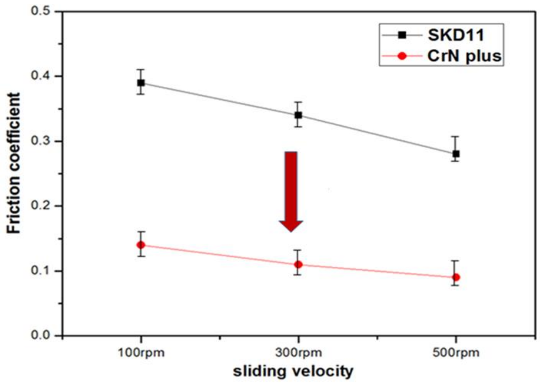

Fig. 11 Rail roll forming dimensional accuracy

quality process capability value for the width dimensional accuracy of the roll forming region of the guide rail of the roll forming system from the experimental results and as a result, the quality processing ability (Cp) of 1.92 ~ 2.20 on average quality was obtained. Therefore, based on the results of this study, the production process has been innovated and excellent quality process capability, which is reliable, appeared.

4. Conclusion

Real time smart dissimilar material roll forming applied with intelligent roll design methods was studied and the following conclusions were obtained. The final strain rate of the real time smart dissimilar material roll forming process was 2.14 mm/mm, which was smaller compared to that of the single material process, which was shown to be 2.71 mm/mm. The variations of strain rates among individual processes were considerably smaller compared to the single material process.

When the dissimilar material roll forming process design method was applied, the strain rates of material decreased considerably.

In the case of the dissimilar material roll forming, since the variations of strain rates and the strain rates of bent regions are considerably smaller as with the strain rates of materials, the durability and precision of materials and rolls during roll forming were improved considerably.

References

1. Son, J. H., Han, C. W., Ryu, K. J., Kang, H. D. and Kim, C. H., "Analytical and Experimental Study on the Quality Stability of Multi Roll Forming Process", Journal of the Korea Academia-Industrial cooperation Society, Vol. 16, No. 10 pp. 6977-6984, 2015.
2. Kang, B. S. and Kim, N. S., “A Study on Roll Wear in the Roll Forming Process”, KSME, Vol. 27, No. 11, pp.1881-18. 88, 2003.
3. Kim, K. H., Yoonh, M. C., “Development of a Roll-Forming Process of Linearly Variable Symmetric Hat-type Cross-section,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 14, No. 4, pp. 118-135, 2015.
4. Chen, W., Nonlinear Analysis of Electroni Prognostics, Doctoral dissertation. The Technical Univer-sity of Napoli, Napoli, Italy, 1991.
5. Sheeja, D., Tay, B. Krishnan, K.,Nu\ng, L. N. Nung, “Tribological characterization of diamond-like carbon (DLC) coatings sliding
6. Tsujikawa, M., Morishige, T., “Application of Friction Stir Welding to Castings”, Journal of the Korean Foundrymen’s Society, Vol.29, No.4, pp.165-168, 2009.
7. Kim, G.. “DLC coatings”, Diamond and Related Materials, Vol. 12, Pp. 1389-1395, 2003.
8. Subramanian, G. and Raghunandan, C., "On improving the fatigue life of U-form bellows", Journal of materials processing technology, v.41 no.1, pp.105 - 114, 1994.
9. Kenji Yamamoto, Katsuhiro Matsukado, “Effect of hydrogenated DLC coating hardness on the tribological properties under water lubrication”, Tribology International, Vol. 39, pp. 1609-1614, 2006.
10. Lee, C. G., Hwang, S. J., Choi. Y. M., “Comparative Study to the Tribological Characteristics of graphite Nano Lubricants after Thermal Degradation”, KSTLE Vol. 24, pp.190~195, 2008.
11. Kim, Y. I., Kim, J. H., Jeong, Y. C. and Kim, N. S., “Buckling Analysis of Roll Forming Process using Finite element method”, KSME, Vol. 27, No. 9, pp.1451-1456.
12. Jeong, B. Y., “A Study on the Hard Coating and Plasma Duplex Surface Treatment of Cast Irons”, Doctoral Thesis, Metal Engineering, Inha Univeristy, Korea, 2001.
13. Kim, J. G., Park, O, J., Hon, S. M., “Tough High Thermal-Conductivity Tool Steel for Hot Press Forming,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 15, No. 3, pp. 130-134, 2016.
14. Kim, K. Y., Choy, L. J., Shin, H. I., Cho, J. H., Lee, C. H. and Kang, M. C., “Characteristics of Mechanical Properties and Micro Structure according to High-Frequency Induction Heating Conditions in Roll Forming Process of a Sill Side Part,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 16, No. 6, pp. 87-94, 2017.