A Study on Smart Roll Forming Based on Real Time Process Data

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Abstract

Roll forming refers to the production of long plate molded products such as panels, pipes, tubes, channels, and frames by continuously causing bending deformation to thin plates using rotating rolls. Since 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 being used in diverse industrial fields as a very important processing method. Since the roll forming method mainly depends on the continuous bending deformation of the plate materials, the time and cost used for heterogeneous materials developed in the process are relatively large when seen from the viewpoint of plastic working because many processes are continuously implemented.

Existing studies on the roll forming manufacturing as such involve the losses of large amounts of time and materials when raw materials or product types are changed, can hardly secure the uniformity of formed shapes and the quality of sizes, and cannot detect all defects occurring in mass production and the dimension. Although dedicated lines with fixed settings for individual products may be considered for the foregoing reasons, the formation of individual dedicated roll forming lines for individual products faces great difficulties due to excessive manufacturing costs.

Therefore, in this study, a real - time process data based smart roll forming that can be applied to multiple products was studied. As a result of such a study, a roll forming system was implemented that remembers and automatically sets changes in fine 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 and secures the uniformity of products so that more competitive precise slide rail products can be mass-produced with improvements in the quality, price, and productivity of products. In addition, smart roll forming process designs were numerically analyzed and the results were applied so that targeted shapes can be approached faster, the reactions in reduction processes by step can be evenly distributed to reduce the intensity fatigue of each process roller, the productivity can be improved, and, in particular, fine cracks or damage to rollers can be prevented thereby removing the fundamental cause of the occurrence of mass defects.

• Introduction

Products such as slide rails, shape steel, channels, angles, and welded pipes are manufactured through steel plate roll forming processes (Sheeja etc. 2003). 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. Since roll forming methods have advantages in terms of mass production as their 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(Tsujikawa & M., Morishige, 2009). 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(Jeong, 2001), .

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(Lee etc., 2008). . 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(Kang&Kim, 2003) . 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. 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. 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(Son etc., 2015). 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. 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. 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.

- **Configuration and interpretation of real time smart roll forming system**

- **Real time dissimilar material roll forming system**

Figure 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.
Figure 2 shows 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.

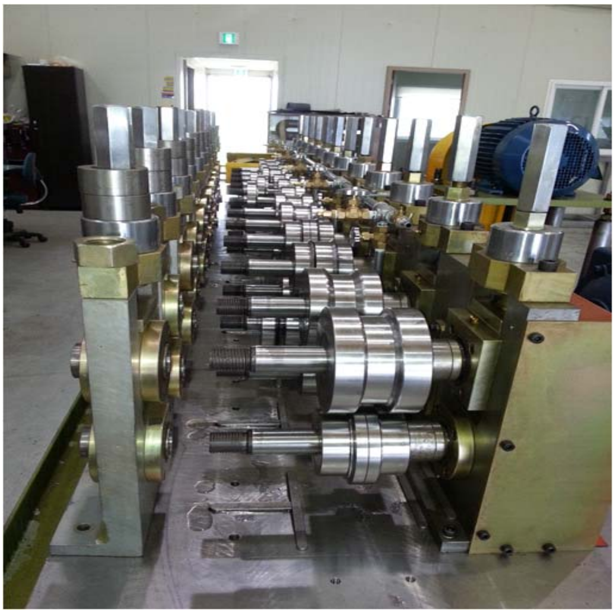

Figure 1. Dissimilar material forming roll system

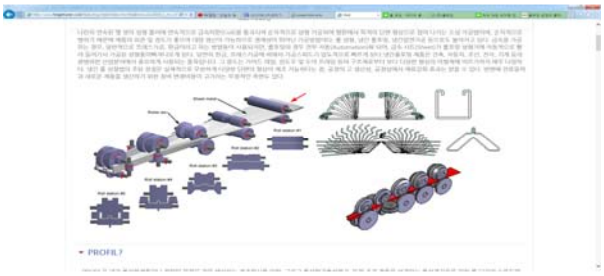

Figure 2. A diagram of the real time smart roll forming stage and the section design

Figure 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.

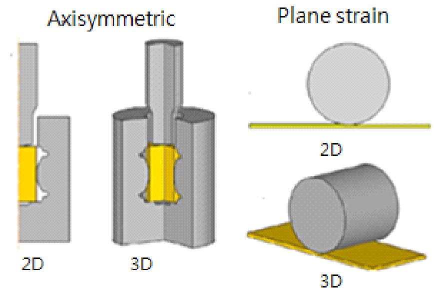

Figure. 3 Block diagram of nonlinear analysis of 3D shapes

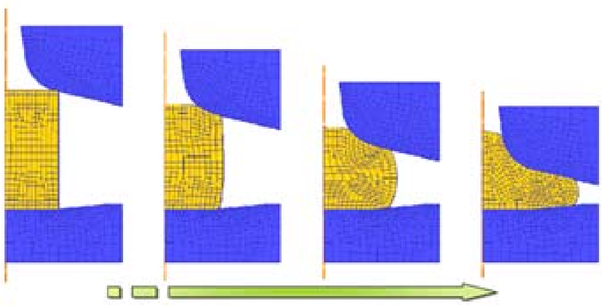

Figure. 4 Process of nonlinear analysis by Deform-2D

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.

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 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.

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

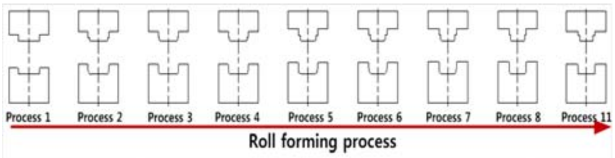

Figure 5 Single material design roll forming process analysis process

Figure 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.

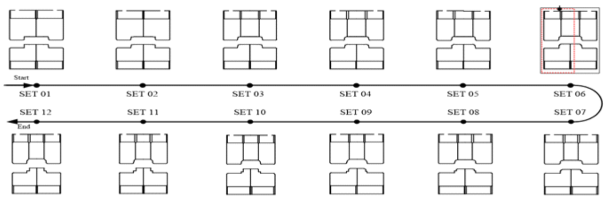

Figure 6. Dissimilar material design smart roll forming process analysis process

- **Results and discussion**

With regard to the strain rates of roll forming materials for single material roll forming designs, as shown in Figure 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. 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 Figure 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.

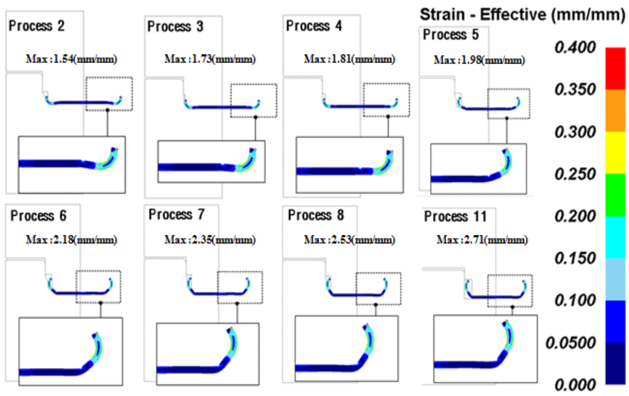

Figure 7. The amounts of deformation of roll forming materials for single material designs

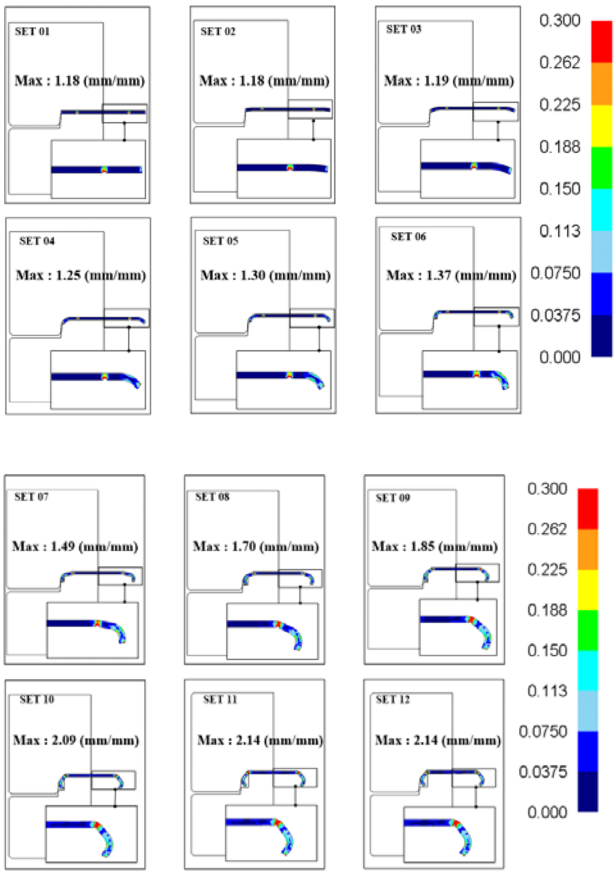

Figure 8. The amounts of deformation of real time smart roll forming materials for dissimilar material designs

- **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,

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