Thin-Walled Structures 92 (2015) 130–136

Contents lists available at ScienceDirect

Thin-Walled Structures

journal homepage: www.elsevier.com/locate/tws

The effects of forming parameters on the cold roll forming of channel section

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ARTICLE INFO

Article history:
Received 9 June 2014
Received in revised form
29 June 2014
Accepted 2 March 2015
Available online 20 March 2015

Keywords:
Cold roll forming
Longitudinal strain
Bow defect
Forming parameters

ABSTRACT

Cold roll forming is one of the complex forming processes which quality of products is highly dependent on the process parameters. In this study the effect of some roll forming parameters of channel section are investigated on the edge longitudinal strain and bow defect of products. These parameters are bending angle increment, strip thickness, flange width of section, web width of section, friction in the roll and strip contact, speed of roll, and distance between the roll stands. It is important to consider these parameters for roll forming process design. Longitudinal bow is one of the main defects in the cold roll forming products which is affected by the bending angle increment. Experimental and numerical results of this study show that bow defect increase with the bending angle increasing. Results of present study show that peak of longitudinal strain in the edge of channel section increases with the bending angle increment and strip thickness increase, but decreases with the flange width, web width and distance between the roll stands increasing. Results show that friction in the roll-strip contact and speed of roll stand does not have any effect on the edge longitudinal strain.

1. Introduction

In the cold roll-forming process, a long metal strip is deformed progressively through a series of rotating rolls in several stands, in order to achieve a required cross-section, with no reduction in the strip thickness, except in the localized bend regions (Fig. 1). Being a progressive and continuous process, in which small amounts of forming are applied at each pass of rolls, cold roll forming is largely employed to bend a long strip of sheet blank into a desired cross-sectional profile via roller dies.

There are numbers of published experimental and numerical studies of the roll-forming process. Neffussi et al. [1] proposed a kinematical approach for predicting the optimal shape and the deformed length of a metal sheet during the cold roll forming before the first roll stand. The main drawback of this study is that only rigid-plastic behavior was considered. Some defects of cold roll forming products were studied by Ona et al. [2]. They did some experimental tests on the cold roll forming of non-symmetric channel section. They investigated the effect of asymmetry on the some defects such as wrinkling and torsion of non-symmetric channel section. In another study Fewtrell et al. [3] did some experimental investigations of operating conditions of cold roll forming in order to gain a scientific understanding of the process. They investigated effective parameters in the cold roll forming process. These parameters were: distance between two continuous stations, rolls velocity and rolls axisymmetric. Fifty tests were done under varied operating conditions. Their results showed that product quality is achievable by control of forming parameters. Panton et al. [4] proposed a new design method that described the variation of bend angle with distance along the strip both within the roll gap and in the unsupported region. They indicated that forming happened in three regions for asymmetry channel section. First region where the bend angle does not change, second region where the bend angle changes but the strip does not contact the roll and third region where the bend angle changes as a function of the roll geometry. Their results showed that severity of forming related to the maximum longitudinal strain in the strip, and this was a function of the maximum slope of the bend angle curve. As mentioned by Panton et al. [4] longitudinal strain is a useful parameters for forming severity and maximum longitudinal strain can be used as a limitation of forming in every stand of roll forming. Panton et al. [5] in another study investigated longitudinal, transverse and shear strains in the roll forming of channel section. They indicated that longitudinal, transverse and shear strains are in all layers of the sheet and maximum of longitudinal strain happens in the sheet edge.

One of the useful parameters in the design of roll forming line is deformation length. Deformation length can be used to calculate

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http://dx.doi.org/10.1016/j.tws.2015.03.002
0263-8231/

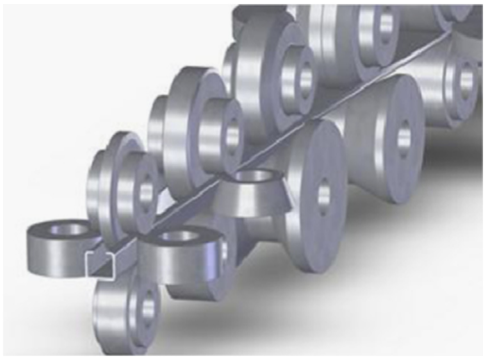

Fig. 1. Profile manufacturing in roll forming process.

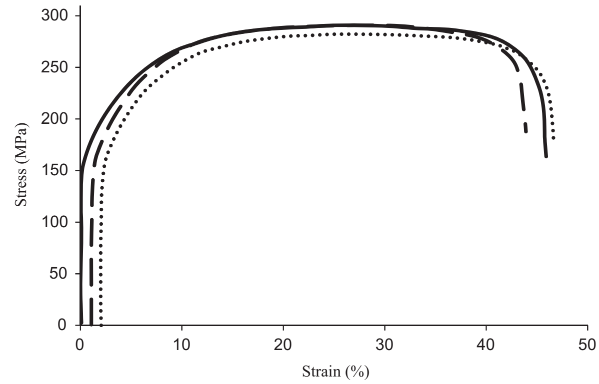

Fig. 2. Tensile test results of three St14 samples.

the distance between two roll forming stands. Bhattacharyya et al. [6] did some analytical and experimental research works on the channel and hat section. They calculated an analytical formula for deformation length using deformation energy minimization. The experimental results of their study showed good agreement with the predicted values of analytical formula. One of the main criteria for designing of roll forming line is to obtain a straight product using minimum number of rolls. Edge longitudinal strain is a parameter that its variation can show product quality. In another study Bhattacharyya et al. [7] measured edge longitudinal strain in the experimental tests of cold roll forming by setup strain gage in 1.5 mm distance from the sheet edge. Their results showed that longitudinal strain was increased by bending angle increasing.

Since the cold roll forming is a complex process, experimental investigation of this process is expensive and time consuming. Beside experimental studies there are some numerical research works on the cold roll forming. Duggal et al. [8] used a simulation program by computer for cold roll forming analysis. This numerical program was used to analysis of simple cross-section profile such as U, V and C channel. Their results showed that residual strain which obtained from numerical was less than Bhattacharyya's experimental results. As a result, time and cost of process design and development can be reduced using a numerical method. In another numerical study Han et al. [9] investigated effects of forming parameters on the longitudinal strain of a channel section with an outer edge. In this study a finite strip method was used for investigation. Lindgren [10] used finite element analysis to investigate the effect of bending angle and material strength on the longitudinal strain and deformation length of channel section. Result of this study showed that the peak of longitudinal strain decreased and the deformation length increased when the yield strength was increased. Hong et al. [11] presented a numerical program for cold roll forming investigation. They estimated the forming length considering some factors for channel section. These factors were material properties, sheet thickness, roll diameter, roll velocity and deformation of material. Bui and Ponthot [12] used a three dimensional simulation for cold roll forming process. In their study finite element code of Metafor was used in all simulations and some parameters were investigated such as friction, roll velocity, material properties and distance of stands. Results of this study showed that yield limit and work hardening exponent had significant impacts on the product quality.

Zeng et al. [13] studied on the optimization design of cold roll forming based on the Response Surface Method (RSM). The optimization process was performed, with the springback angle as the objective function and maximum edge membrane longitudinal strains as constrain condition.

Finite element software of Metafor was used by Rossi et al. to model the cold roll forming of channel profiles which made of high-strength and stainless steels [14]. The numerical results, expressed in terms of corner strength enhancement versus radius-to-thickness ratio, were compared against an existing predictive model. Wiebenga et al. [15] used robust optimization techniques to determine the optimal process settings of adjustable tools in the final roll forming stand. Advanced High Strength Steel (AHSS) was used in the roll forming of V-section profile and results showed a significant amount of longitudinal bow and springback in the final product.

Tehrani et al. [16] studied the 'localized edge buckling' in cold roll-forming of symmetric channel sections. They used finite element simulation in their study to show that there exists a particular limit for the roll angle in the forming stand.

In this paper, numerical and experimental methods are used to investigate the effect of some forming parameters in the cold roll forming of channel section. Bowing defect which is one of the main defects in the roll forming products is investigated experimentally and numerically. Effect of some parameters such as bending angle increment, strip thickness, flange width of section, web width of section, friction in the roll and strip contact, speed of roll stand, and distance between the roll stands is investigated on the edge longitudinal strain of channel section.

2. Methodologies

2.1. Experimental material and properties

The materials used in this study was steel sheets of St14. Mechanical properties of St14 steel was measured by tensile test base on the ASTM-E8 standard [17]. This test was repeated three times for more accuracy. Fig. 2 shows stress–strain curves of these three tests. Average mechanical properties of St14 from tensile tests are summarized in Table 1. These mechanical properties are Yield Stress (YS), Ultimate Tensile Strength (UTS), work hardening exponent (n), work hardening coefficient and elongation. Hollomon's equation ($\sigma = K\varepsilon^n$) was used to model the plastic behavior of sheet material.

2.2. FEM analysis of cold roll forming

Numerical investigation of cold roll forming was done using a commercially available finite element code Abaqus/Explicit 6.10. The FEM model consists of a strip and four rolls as shown in Fig. 3. The model consists of two forming stands that the first stand is used as a belt feeder to the second stand. Rolls were modeled as analytical rigid parts, because they have negligible deformation. The sheet strip was modeled as a deformable part using four node Kirchhoff thin shell elements (S4R). Whereas the channel section is symmetric, just half of section was modeled. Fig. 4 shows the method which was used to mesh the strip. Fine mesh was used in the bending region of strip because of more deformation and coarse mesh with 1 mm length was used for other regions of the strip (web and flange zone).