



Multiple Process Parameter Optimization of Roll Forming on High Strength Steel using TOPSIS

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Abstract

The process parameters in roll forming play a significant role in the quality of the end shaped product. The present research deals with an effective approach; TOPSIS has been applied to experimental results of roll forming on high strength steel. The present research focuses on input process parameters including the roll forming line velocity, the inter distance between roll stations, the roll gap, and the diameter of the rolls. The responses considered as a longitudinal strain. An optimization procedure TOPSIS (Technique of Order Preference by Similarity to Ideal Solution) originates from the concept of displaced ideal solution. TOPSIS used to predict the optimum process parameter. The main objective of this study is to obtain for minimum elastic longitudinal strains, for each roll station. The results reveals that the inter distance between the roll stations plays a significant role in the roll forming process.

Keywords: Metal forming, TOPSIS, optimization longitudinal strains

1. Introduction

The rolling process is one of the most popular processes in manufacturing industries. This involves the passing of metal stock through a pairs of rollers, which causes the decreases in cross-sectional area, it has numerous applications of slabs, bars, rods, plats & heavy sections [1, 2]. The quality of the final product depends on the forming process parameters including strain across rolled strip thickness, rolling torque and roll separation force [1]. The primary purpose in analyzing metal forming operations is to calculate the most influence parameters which effect the target of the manufactures. So the researchers are mainly concentrating on optimization of parameters. John paralikas et al.[3] has conducted experimental modeling on AHSS material to get the U-sectioned symmetrical profile and concluded that the longitudinal strains were influenced by the inter-distance between the roll stations. Minijin et al. [4] analyzed that by modifying the design of target pass the longitudinal strains along the direction of rolling affects the final product. Dyi-Cheng Chen et al. [5] examined that behavior of plastic deformation for the porous V section sheet and concluded that the roll design parameters are more significant. Sombolstan et al. [6] optimized various roll design parameters and different types of roll profiles and examined that different types of passes plays a major roll for energy consumption (i.e., box square sequence followed by oval square and diamond square. Xiong et al.[7] modeled a plain strain rolling by combining fem and boundary element method, and observed that the rolling torque, roll separating force and the contact pressure has been improved. Karen et al. [8] proposed an analytical method for various roll passes and the output have compared with analytical solution, numerical method and experimental values and finalized that generalized upper bound approach valid with good results. E

Roszkowska et al. [9] suggested that TOPSIS method is used to develop multi criteria decision making model to crisp & interval data.

2. Procedures and Methods

In the present study, AHSS DP600 HDG is considered as the work piece material, the properties of the material are[3,20] initial strip thickness 2 mm, friction coefficient 0.2, density 7860kg/m³, young's modulus of elasticity 2.1GPa, Poisson ratio 0.3, Yield limit 417MPa, initial Plastic strain 0.001911, strength coefficient K=1120, hardening coefficient n=0.171[3,10] Table1, gives the assignment levels of process parameters(viz., line velocity, inter distance between roll stations, roll gap Diameter of the rolls). The output responses (viz., longitudinal strains) for the assigned process parameters as per L9 orthogonal array [3] are presented the experimental data, following refs.[9 10] Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) is performed to identify the optimum process parameters for achieving possible low longitudinal strains at every roll stations.

2.1. TOPSIS Procedure

Technique of Order Preference by Similarity to Ideal Solution (TOPSIS). This method considers three types of attributes or criteria a) Qualitative benefit attributes /criteria b) Quantitative benefit attributes c) Cost attributes or criteria. In this method two artificial alternatives are hypothesized, Ideal alternative: the one which has the best level for all attributes considered. Negative ideal alternative: the one which has the worst attribute values. TOPSIS selects the alternative that is the closest to the ideal solution and farthest from negative ideal alternative.

2.1.2. Input to TOPSIS

TOPSIS assumes that we have m alternatives (options) and n attributes/criteria and we have the score of each option with respect to each criterion.

Let x_{ij} score of option i with respect to criterion j

We have a matrix $X = (x_{ij})$ $m \times n$ matrix. Let J be the set of benefit attributes or criteria (more is better) Let J' be the set of negative attributes or criteria (less is better)

2.1.3. Steps of TOPSIS

Step 1: Construct normalized decision matrix. This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria.

Normalize scores or data as follows:

$$r_{ij} = x_{ij} / (\sum x_{ij}^2)^{1/2} \text{ for } i = 1, \dots, m; j = 1, \dots, n$$

where m= alternatives n = attributes/criteria

x_{ij} = score of option i with respect to criterion j

$X = \{x_{ij}\}$ 4×4 score matrix.

J = set of benefit attributes: (more is better)

J' = set of negative attributes: (less is better)

Step 2: Construct the weighted normalized decision matrix.

Assume we have a set of weights for each criteria w_j for $j = 1, \dots, n$. Multiply each column of the normalized decision matrix by its associated weight. An element of the new matrix is:

$$v_{ij} = w_j r_{ij}$$

Step 3: Determine the ideal and negative ideal solutions.

Ideal solution.

$$A^* = \{v_1^*, \dots, v_n^*\}, \text{ where}$$

$$v_j^* = \{ \max (v_{ij}) \text{ if } j \in J; \min (v_{ij}) \text{ if } j \in J' \}$$

Negative ideal solution.

$$A' = \{v_1', \dots, v_n'\}, \text{ where}$$

$$v_j' = \{ \min (v_{ij}) \text{ if } j \in J; \max (v_{ij}) \text{ if } j \in J' \}$$

Step 4: Find the separation measures for each alternative.

The separation from the ideal alternative is:

$$S_i^* = [\sum (v_{ij}^* - v_{ij})^2]^{1/2} \quad i = 1, \dots, j$$

Similarly, the separation from the negative ideal alternative is:

$$S_i' = [\sum (v_{ij}' - v_{ij})^2]^{1/2} \quad i = 1, \dots, m$$

Step 5: Calculate the relative closeness to the Negative solution

$$C_i^* = S_i' / (S_i^* + S_i') \quad 0 < C_i^* < 1$$

Select the option with C_i^* closest to 0.

This technique is preferable to achieve minimum longitudinal strains in all roll stations. In this study the experimental values were adopted from [3], Table 1, presents the assignment levels of input parameters (viz., line velocity, inter distance between roll stations, roll gap and diameter of rolls). The response parameters (viz., longitudinal strains) for the process parameters as per L_9 orthogonal array presented in Table 2.

Table 1: Assignment levels of process parameters

Variables	Level-1	Level-2	Level-3	Units
LV	750	1000	1200	mm/s
IRD	350	450	550	mm
RG	0	3	6	mm
DR	100	140	160	mm

LV: line velocity, IRD: inter distance between roll

Stations RG: Roll gap, DR: Diameter of the rolls,

Table 2: L_9 standard orthogonal array

Exp No.	LV	IRD	RG	DR
1	750	350	0	100
2	750	450	0.3	140
3	750	550	0.6	160
4	1000	350	0.3	160
5	1000	450	0.6	100
6	1000	550	0	140
7	1200	350	0.6	140
8	1200	450	0	160
9	1200	550	0.3	100

Table 3: Performance output responses for the assigned process parameters as per L_9 orthogonal array

Longitudinal Strain					
Exp-no	Lrs-1	Lrs-2	Lrs-3	Lrs-4	Lrs-5
1	0.1664	0.2044	0.201	0.2519	0.2462
2	0.1682	0.1942	0.1284	0.2363	0.174
3	0.1376	0.1707	0.0339	0.1838	0.0962
4	0.1367	0.2063	0.2177	0.2565	0.2812
5	0.1412	0.1578	0.1387	0.2266	0.0629
6	0.1412	0.1963	0.1896	0.2191	0.0968
7	0.1065	0.1993	0.2175	0.2809	0.2904
8	0.1724	0.1827	0.1674	0.2194	0.1887
9	0.1264	0.1701	0.1849	0.2098	0.1571

2.1.4. The weighted normalized decision matrix

Table 4: Normalized matrix

Normalized Matrix					
Longitudinal Strain					
Exp-no	Lrs-1	Lrs-2	Lrs-3	Lrs-4	Lrs-5
1	0.3812	0.3632	0.3867	0.3601	0.4240
2	0.3854	0.3451	0.2470	0.3378	0.2997
3	0.3152	0.3033	0.0652	0.2628	0.1657
4	0.3132	0.3666	0.4189	0.3667	0.4843
5	0.3235	0.2804	0.2669	0.3240	0.1083
6	0.3235	0.3488	0.3648	0.3132	0.1667
7	0.2440	0.3542	0.4185	0.4016	0.5001
8	0.3950	0.3247	0.3221	0.3137	0.3250
9	0.2896	0.30228	0.3558	0.2999	0.2706

Table 5: weighted matrix

weighted Matrix					
Longitudinal Strain					
Exp-no	Lrs-1	Lrs-2	Lrs-3	Lrs-4	Lrs-5
1	0.0762	0.0726	0.0773	0.0720	0.0848
2	0.0771	0.0690	0.0494	0.0676	0.0599
3	0.0630	0.0607	0.0130	0.0526	0.0331
4	0.0626	0.0733	0.0838	0.0733	0.0969
5	0.0647	0.0561	0.0534	0.0648	0.0217
6	0.0647	0.0698	0.0730	0.0626	0.0333
7	0.0488	0.0708	0.0837	0.0803	0.1000
8	0.0790	0.0649	0.0644	0.0627	0.0650
9	0.0579	0.06046	0.0712	0.0600	0.0541

Table 6: Separation Ideal solution

Separation Ideal solution (squares)					
Longitudinal Strain					
Exp-no	Lrs-1	Lrs-2	Lrs-3	Lrs-4	Lrs-5
1	0.0008	0.0003	0.0041	0.0004	0.0040
2	0.0008	0.0002	0.0013	0.0002	0.0015
3	0.0002	0.0000	0.0000	0.0000	0.0001
4	0.0002	0.0003	0.0050	0.0004	0.0057
5	0.0003	0.0000	0.0016	0.0001	0.0000
6	0.0003	0.0002	0.0036	0.0001	0.0001
7	0.0000	0.0002	0.0050	0.0008	0.0061
8	0.0009	0.0001	0.0026	0.0001	0.0019
9	0.0001	1.9E-5	0.0034	0.0001	0.0011

Table 7: Separation Negative solution

Separation Negative solution (squares)					
Longitudinal Strain					
Exp-no	Lrs-1	Lrs-2	Lrs-3	Lrs-4	Lrs-5
1	0.0000	0.0000	0.0000	0.0000	0.0001
2	0.0000	0.0000	0.0006	0.0000	0.0002
3	0.0003	0.0002	0.0036	0.0004	0.0016
4	0.0003	0.0000	0.0001	0.0000	0.0006
5	0.0002	0.0003	0.0004	0.0001	0.0027
6	0.0002	0.0000	0.0000	0.0001	0.0016
7	0.0009	0.0000	0.0001	0.0000	0.0007
8	0.0000	0.0001	0.0001	0.0001	0.0001
9	0.0004	0.00017	0.0000	0.0002	0.0004
A'	0.0000	4.7E-14	0.0001	0.0000	0.0007

Table 7: The relative closeness

Exp No	Si*	Si ⁺	Ci*
1	0.0976	0.0126	0.8860
2	0.0631	0.0284	0.6896
3	0.0189	0.0781	0.1946
4	0.1076	0.0305	0.7791
5	0.0450	0.0603	0.4274
6	0.0653	0.0439	0.5980
7	0.1101	0.0423	0.7225
8	0.0749	0.0182	0.8045
9	0.0677	0.03408	0.6652

3. Analysis of data and discussion of results

3.1. Development of Mathematical models

The experimental values are used in order to obtain the mathematical relation between the process & performance parameters, Based on the data is used to fit a second order model for longitudinal strain. The coded form of factors i.e. -1 to +1 are given to SPSS software to estimate the model equation is shown in equation (1)

$$LRS = 0.226 - 2.643e^{-7}LV^2 + 1.755e^{-6}IRD^2 - 0.21RG^2 + 6.172e^{-5}LV * RD - 1.137e^{-5}IRD * RD + 0.002RG * RD \dots (1)$$

(R-square value 0.999)

3.2. Effect of Process Parameters

The R-square value of 0.999 shows that 99.9% of the variability in longitudinal strain as shown in equation (1). There is no significance of individual parameters LV, RG and RD on the longitudinal strain. IRD has significant effect on longitudinal strain, but its interactions with LV, IRD & RD has less significant effect on longitudinal strain.

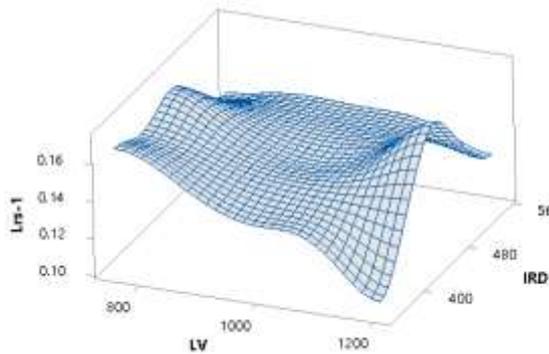


Fig. 3.1: Interaction of line velocity with inter roll distance(RS1)

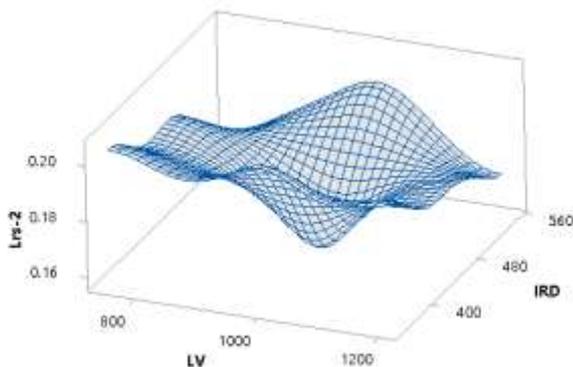


Fig. 3.2: Interaction of line velocity with inter roll distance (RS 2)

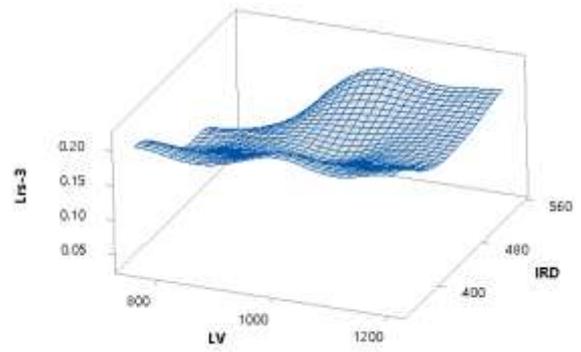


Fig. 3.3: Interaction of line velocity with inter roll distance (RS 3)

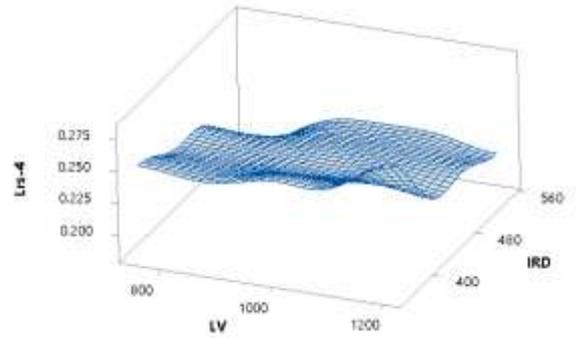


Fig. 3.4: Interaction of line velocity with inter roll distance (RS4)

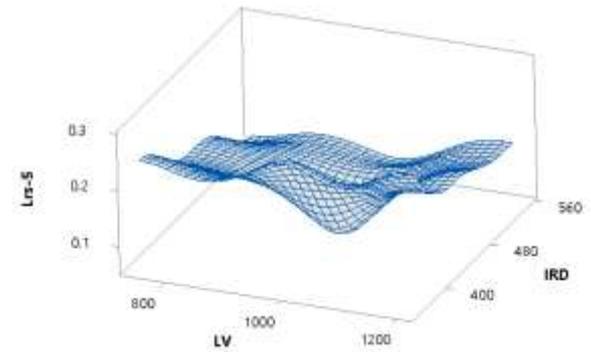


Fig. 3.5: Interaction of line velocity with inter roll distance (RS 5)

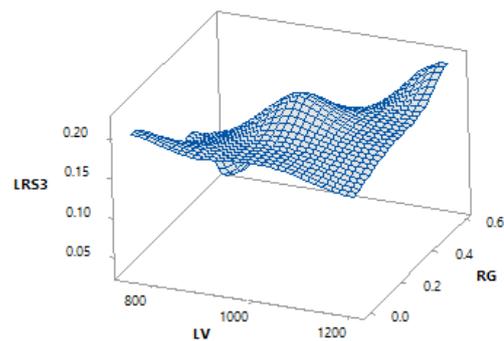


Fig. 3.6:Interaction of line velocity with roll gap (RS 1)

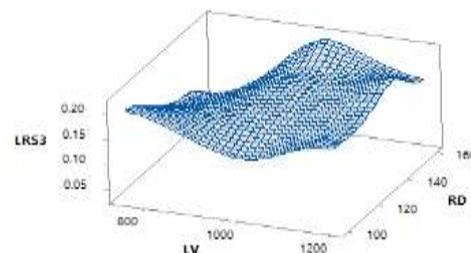


Fig. 3.7 :Interaction of line velocity with roll dia (RS 1)

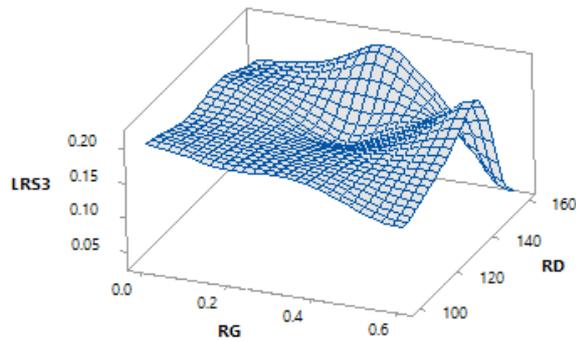


Fig. 3.8: Interaction of Roll Gap with roll dia (RS 1)

3.3. Effect of process parameters

The combine effect of two process parameters on the response parameters is known as interaction effect. For the interaction plot, the two process variables alter holding other three process parameters at the central value and identify the effect on the output response

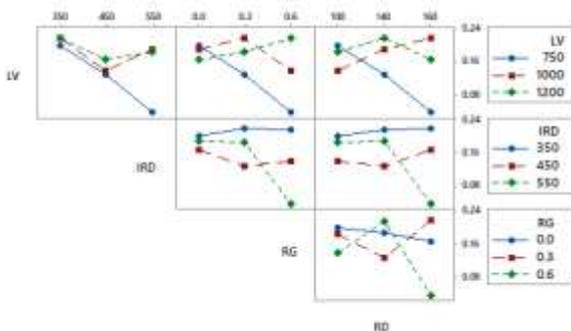


Fig. 3.9: Effect of process parameters

4. Conclusion

The results reveals that the inter distance between the roll stations plays a significant role in the roll forming process contribution of each process parameter on the longitudinal strain are shown. From the model it can be observed that the longitudinal strain decreases with an increase the inter roll distance. The effect of inter roller distance dominating on longitudinal strain followed by roll gap, line velocity; and roll diameter

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