International Journal of Innovations & Research Analysis (IJIRA)
(An International Quarterly Multidisciplinary Peer Reviewed Refereed Journal)
e-ISSN :2583-0295, Impact Factor: (Cosmos 7.662 & I2OR 5.105), Volume 06, No. 02(II), April- June, 2026, pp 13-24

Optimization of Process Parameters in Roll Forming Process: A Case Study at M/S Chaitanya Steel Shape Pvt. Ltd., Jalgaon (MS), India

Pankaj.P.Gade[1*] | Dr.Vijaykumar .H. Patil[2]

[1]Ph.D Research Scholar, KBC North Maharashtra University, Jalgaon, Maharashtra, India.
[2]Principal, Godavari College of Engineering, Jalgaon, Maharashtra, India.

[*]Corresponding Author: gadepankajp@gmail.com

Citation: Gade, P. & Patil, V. (2026). Optimization of Process Parameters in Roll Forming Process: A Case Study at M/S Chaitanya Steel Shape Pvt. Ltd., Jalgaon (MS), India. International Journal of Innovations & Research Analysis, 06(02(II)), 13–24.

ABSTRACT

The process of roll forming involves sheet metal feed through a sequence of rollers, each of which imparts a specific shape to the metal. These rollers collaborate to produce the desired cross-section. Because of its consistency with ease of repetition, rolling is an excellent method for efficiently producing huge quantities of metal parts. Roll forming enables production for long components with intricate cross-sections from sheet materials that exhibit high strength. This paper aims to develop a fundamental understanding of the effect of control factors such as roll load at entry and exit, roll speed roller diameter, temperature of rollers, bending pressure, percentage reduction in thickness of roll sheet on final shape in the roll formed parts by using Taguchi's method of process optimization. This study aimed at enhancing the quality characteristic of roll forming process, by optimizing some roll forming process parameters using the Taguchi method. Also, the effect of process parameters in roll forming of mild steel has been investigated. To analyze how roll forming process parameters affect final shape of the roll formed sheet, an orthogonal array, principal effect analysis, signal-to-noise ratio are applied. Results indicate that the optimal conditions for minimizing shape geometry of roll formed sheet include an entry and exit load, roll speed, no. of pass and such others. Additionally, the Taguchi method for Design of experiments (DOE) is used to explore significant effects, including interactions among roll forming process.

***Keywords**: Roll Forming, Taguchi Method, Design of Experiments (DOE), Optimization.*

Introduction

Roll forming is a metalworking process where sheet metal is progressively shaped through a sequence of bending operations. This process takes place on a roll forming line, where the metal sheet is passed through multiple roll stations [1]. At each station, there are roller dies one positioned on each side of the sheet. These roller dies can vary in shape and size from station to station, or identical ones might be used in different locations. The roller dies can be positioned above and below the sheet, along its sides, or at various angles. As the sheet moves through the roller dies at each station, it undergoes plastic deformation and bending. Each roll station contributes to one stage of the sheet's bending process to create the final part. Roll forming is versatile and can produce a wide range of cross-sectional profiles from the sheet metal. Metal forming is one of the primary manufacturing processes. Rolling is the reduction of the thickness of a work piece by passing it through the rolls [10].

In today's manufacturing scenario, ensuring quality is crucial due to the complex working conditions in which sheet metal components are used [2]. Quality can be measured by the level of customer satisfaction throughout the product's service life. It is clear that careful selection of process parameters affecting quality is essential [3]. Effective defect prevention through controlled quality measures leads to fewer trial-and-error and tryout processes. As parts become more complex and

[*] *Copyright © 2026 by Author's and Licensed by Inspira. This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work properly cited.*

demands for high quality increase, along with the use of advanced optimization techniques, there is a growing need for thorough research in sheet metal roll forming process.

Literature Review

Saral Dutta [16] reviewed the sheet metal forming process in which sheet metal stock is rolled through a pair of rolls. Mainly two types of rolling process - flat and profile rolling. In flat rolling the final shape of the product i) "strip" (thickness less than 3 mm,) or ii) plate (thickness more than 3 mm). In profile rolling, the final product i) round rod or ii) other cross sections shaped products such as structural sections (beam, channel, joist, rails, etc).

Abrao et. al. [17] observed the influence of rolling pressure and number of passes on the surface integrity of fully annealed AISI 1060 high carbon steel. A comprehensive investigation on surface integrity is carried out along with the mechanical properties. The findings were increase in surface hardness and ultimate tensile stress, Yield strength negatively affect the deep rolling.

Paralikas, J, Salonitis, K. and Chryssolouris, G [6], researches roll forming parameter, they used DP600 for their studies. They learned that the velocity of the rolling process can be regulated. It largely alters the strain of material. Bending of material and forming defects in material due to increasing in the velocity.

Park, H, Anh T. and Dang, X [7] researches on mechanical behavior of aluminum sheets by using MATLAB software. An application of the ANN-GA hybrid approach is describe in this paper for modeling and optimizing the RF process of an aluminum car door belt.

Paralikas, J., Salonitis, K. and Chryssolouris, G [8], studied roll forming parameters, they used DP780 material for their studies. They learned, presented and discussed that calculated decrease in the peak longitudinal strains of up to 28%, along with decrease in thickness of up to 38%.

Paralikas, J., Salonities, K. and Chryssolouris, G. [9], analyzed roll forming parameter, they used DP600-HDG for their studies. They compare the total longitudinal strains along the roll-forming direction

Problem Statement

Roll forming process of sheet metal is a major production method used in large fields of industry. In whole year, productions of extremely complex parts are possible due to technological advances. In Sheet metal roll forming processes, sheet metal convert into different shapes for a large variety of finished parts. So, the optimize parameters in sheet metal roll forming process must be to determine to get the optimal value. So that without increase the cost operation and reduce the cycle time, production rate can be increased. Then, high demand and more profit will achieve to manufacturer.

Objective and the identified input-output parameters

There are 2 main objectives in this study:

- To find the optimize parameters in roll forming process.
- To synthesize the parameters by using Taguchi Method.

The diagnosed output parameters that affect product quality roll formed sheets are as follows:

- Strip thickness variation at exist.
- Flatness of strip at exist
- Power utilized.
- Productivity.

Following are the input parameters:

- Entry Load
- Load at Exit
- Rolling speed
-) Bending load.

Therefore, the Objective to minimize strip thickness variation at exists within permissible value.

Experimental Methodology: The Taguchi's approach

Genichi Taguchi, a Japanese engineer, proposed several approaches called as "Taguchi Methods" for experimental designs. In this method an orthogonal array utilizes, that is a form of fractional factorial design in which a representative set of all possible combination of experimental conditions. A balanced comparison of levels of the process parameters along with significant reduction in the total number of required simulations both can be achieved by this method. The quality engineering method developed by Taguchi which introduces a novel experimental strategy that utilizes a modified and standardized version of design of experiments (DOE). Essentially, DOE principles are a specific application of the Taguchi approach. It permits for the cost effective study of how multiple variables which influence a desired quality characteristic. By studying the impact of individual factors, identification of optimal combination of these factors. [4].

Taguchi designs experiments using specially crafted tables called orthogonal arrays‖ (OAs). These tables simplify the design process and ensure consistency while reducing the number of experimental trials needed to explore the entire parameter space [5]. The results of these experiments are then changed into a signal-to-noise (S/N) ratio. Recommendation by Taguchi for using the S/N ratio to evaluate deviation in between quality characteristics and desired values. Typical three parameters of quality characteristics analyzed with the S/N ratio: "lower-the- better," "higher-the-better," and "nominal-the-better." For each level of process parameters, the S/N ratio is calculated. Generally, a higher signal-to-noise ratio means better quality characteristics. Thus, optimal process parameters yield the highest S/N ratio. Additionally, a statistical analysis of variance is carried out to determine the significance of each process parameter. for predicting the optimal parameter combination, the S/N ratio and ANOVA analyses combine performed. At the end, for verification of optimal parameters identified through the design, a confirmation experiment is done.

Taguchi's Procedure

Taguchi methods to quality control have been used to optimize the process parameters of engineering experiments [13]. The following procedure carried out to determine use of Taguchi's parameter design:

- Optimization of determine Quality Characteristic
- Find the Noise Factors and Test Condition.
- Find the Control Factors and their levels.
- Experimentation for design the Matrix and Procedure to define the Data Analysis.
- Experimentation for Conduct the Matrix.
- Data analysis and finding optimum level of Control Factors.
- Determine the output at these levels.

Steps in Taguchi's design of experiments (DOE) using MINITAB [12]

For the optimization of experimental designs for performance quality and cost, Taguchi methods of experimental design provide a simple, efficient and systematic approach. In many manufacturing industry, it has been verified successfully. Following are the important steps in Taguchi's Design of Experiments (DOE) using MINITAB

- Pick control factors
- Create Taguchi Design to produce a Taguchi outline (orthogonal exhibit) If needed, rename the elements, change the factor levels
- For changing the units, Display Design to be utilize (coded or on the other hand un-coded) for that MINITAB communicates
- Play out the analysis and gather the reaction information.
- For dissect the exploratory information, Taguchi Design use to analyze.
- For choosing new factor settings, forecast Results to expect S/N proportions and reaction attributes utilize.

Practical Work: A case study at M/S "Chaitanya Steel Shape Pvt Ltd, Jalgaon (Maharashtra) India

Realization of practical work has been done at the manufacturing company "Chaitanya Steel

Shape Pvt Ltd, Jalgaon (Maharashtra)" [11]. Established in 1985 the Chaitanya Steel shape Pvt. Ltd. is an ISO9001:2015 certified company. With total area of 4725 Sq. mtrs, Chaitanya Steel Shape Pvt Ltd deal in Sheet Metal Press Parts, Engineering Fabrication, CNC Wire cutting, CNC Plasma & Oxyfuel Cutting and Colour Coated Roofing- Siding, Design & Manufacturing of Press Tools & Jigs-Fixtures etc. with highly sophisticated and well equipped manufacturing plants and equally capable, well trained manpower. It has 80 feet long Roofing and Siding Roll Forming Machine (Double decker), Bending Machine (Weldor make) Size= 8mm x 3000mm, NC Shearing (Nu Gen Trimans make), 7.5 Tons EOT overhead Crane (Span 75 Feet x 110 Feet), Roofing Sheet Crimping Machine. at its plant no 2. These lines serve to produce corrugated profiles for covering roofs, fences, etc.

Figure: Production Line at "Chaitanya Steel Shape Pvt. Ltd., Jalgaon

At Chaitanya Steel Shape Pvt Ltd, Jalgaon, PPGI, PPGL Bare GL sheets are made from Genuine Best Quality Raw Material of Essar, JSW, Tata etc. Sheets are designed and are produced using highly sophisticated machines.

Specification Terms in Roll Forming Machine

- Material Thickness: Roll forming machines are capable to handle a wide range of material thicknesses.
- Material Width: Depending on the design, roll forming machines can process various widths.
-
- Roll Tooling: Roll forming machine having multiple pairs of rollers which gradually shape the material into the desired profile. The specific profile to be formed affects design and configuration of the roll tooling.
- Number of Stations: Roll forming machines having multiple stations or sets of rollers. At each station a specific bending or forming operation is carried out. On the complexity of the profile to be produced, number of stations can vary.
- Line Speed: The speed is an important specification, at which the material is flow through the machine. On the material and profile requirements, line speed can vary.
- Drive System: Roll forming machines runs on electric motors with drive systems giving power to the rollers.
- Roll Forming Process: Roll forming machines can operate in single-pass or multi-pass systems.

To achieve the desired shape, single-pass machines form the entire profile in one pass, while multi-pass machines may require multiple passes.

- Control System: Modern roll forming machines having computerized control systems that permits operators to set and adjust parameters such as roll positions, line speed, and material feed.
- Material Handling: For loading coils or sheets onto the machine and removing finished products, few roll forming machines come with material handling systems.
- Safety Features: To protect operators and ensure safe operation, guards, emergency stop buttons, and safety interlocks like safety features are essential.
- Tooling Changeover: The ability to quickly change roll tooling for different profiles, depends upon the production requirements, which is important for versatility.
- Frame and Construction: Robust and durable machine's frame and construction help to withstand the stresses of roll forming.
- Optional Features: Additional optional features, like cut-off systems, hole punching units, and in-line quality control systems, depends upon the manufacturer and application.

Company Product Names: Rakshak - colour coated roofing & siding [11]

Table: Products

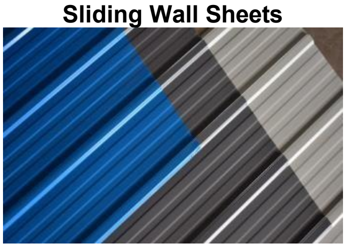
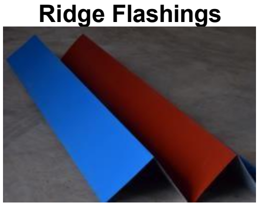
Tilting Sheets	**Roofing Sheets**	**Sliding Wall Sheets**
		
Crimped Sheets	**Ridge Flashings**	**Dome Round Shed Sheets**
		

Table: Product Application

Table: Experimental specifications		
Sr No	**Parameters**	**Specifications**
1	Material used	PPGI, PPGL Bare GL sheets
2	Machine tool used (Roll Forming process)	80 feet long Roofing and Siding Roll Forming Machine (Double decker)
3	Product	Colours coated roofing & siding and Siding (Wall cladding)
4	Sheet thickness	0.3mm to 2.8mm
	Maximal Speed	63/min (Frequency Conversion to Adjust Speed.)
5	The dimension of the product line	About 60m x 3m x3m
6	Total power of the product line	About 65 KW and 40 KW
7	Total Wight	40 Tons

This machine is composed of decoiler, forming machine, hydraulic cutting device, electric control system, hydraulic station, and generator and unloading rack. All parts are placed on a portable trailer which making unit suitable for site working.

Table: Technical Details		
Sr No	**Parameters**	**Specifications**
1	Main forming power	7.5KW
2	Curving motor power	4+1.1+1.1KW
3	Electric cutting power	3KW
4	Roller material	Gcr15 steel
5	Forming Station	10
6	Working speed	Straight sheet 0-12m/min; Arch sheet 13m/min
7	Generator power	30KW
8	Maximum Span	38 M
9	Total Work piece used	9 x 3 (9 experiments)
10	Taguchi's Orthogonal array used	L9

Experimentation

- **DOE No 1: Considering rolling parameters such as entry load, exit load, rolling speed, bending pressure and their levels**

Before proceeding on to further steps, it is necessary to identify the main function and its side effects. It is also important to write down all the factors which affect or influence the thickness variation in rolling process. Out of these factors one has to detect the control and noise factors. Factors affecting a cold rolling operation are listed below.

Table: Control and Noise factors	
Control factors	**Noise Factors**
Entry load	Exit sheet thickness variation
Exit load	Exit sheet thickness variation
Rolling Speed	Vibrations
Bending Pressure	Exit sheet thickness variation

For constructing the matrix for experimentation, only that factors must be taken into consideration, which significantly affect the performance, after listing the control and the noise factors. All other factors are taken as Noise Factors. There is lot of control input factors in a pass such as reduction, tension at entry level, tension at exit level, frictional coefficient, width of strip, rolled material. Experimentation carry out by keeping input material data, the control factors are load at entry, load at exit, speed of rolls & roll bending load. The major noise factors are strip thickness variation at input. The array can be produced accordingly after levels of control factors are decided.

By conducting the experiment, factors and their levels were decided, for that a brain storming session that was conducted among a group of working people and also following the guide lines given by the manufacturer of the rolling process, in the operator's manual. The factors and their levels are shown in the following table.

Table: Input parameters with levels	
Factors i/p variables	**Level**
Load at Entry	3
Load at Exit	3
Speed of Rolls	3
Bending load	3

Factors with their levels in Design of Experiment (DOE) No 1 as follows

Table: Factors, units of measurements and levels				
Factors	**Units of Measurement**		**Levels**	
		1	**2**	**3**
Entry Load	KG	10000	10500	11000
Exit Load	KG	5000	5500	6000
Rolling Speed	m/min	300	350	400
Bending Pressure	Kg/cm^2	60	65	70

In our experiment, four control factors with 3 levels. For this experimentation, widely suitable orthogonal for project is L9 which is available in standard orthogonal array. In above table indicates, experimental layout and selected values of the factors. For variations occur due to the noise factors are studied from each of the 9 experiments. By using the gauge, exit thickness was measured and after finishing one complete pass, thickness variation reports generated. Mentioned below table shows the values to be measured of thickness obtained from different experiments.

Table: Conducting the Matrix Experiment table					
Roller No	**Entry Load**	**Exit Load**	**Rolling Speed**	**Bending Pressure**	**Exit Thickness**
1	10000	5000	300	60	1.3
2	10000	5500	350	65	1.4
3	10000	6000	400	70	1.5
4	10500	5000	300	60	1.2
5	10500	5500	350	65	1.6
6	10500	6000	400	70	1.7
7	11000	5000	300	60	1.4
8	11000	5500	350	65	1.3
9	11000	6000	400	70	1.2

For calculating the S/N ratio, smaller-the-better type of control function was used which is the objective function of thickness variation. Calculation and tabulation for S/N ratios and mean of all the experiments were shown as follows.

Table : S/N ratios and mean

Entry Load (kg)	Exit Load (kg)	Rolling Speed (m/min)	Bending Pressure (Kg/cm^2)	Exit Thickness (mm)	SNRA3	MEAN3
10000	5000	300	60	1.3	-2.27887	1.3
10000	5500	350	65	1.4	-2.92256	1.4
10000	6000	400	70	1.5	-3.52183	1.5
10500	5000	300	60	1.2	-1.58362	1.2
10500	5500	350	65	1.6	-4.08240	1.6
10500	6000	400	70	1.7	-4.60898	1.7
11000	5000	300	60	1.4	-2.92256	1.4
11000	5500	350	65	1.3	-2.27887	1.3
11000	6000	400	70	1.2	-1.58362	1.2

Table: Response for S/N Ratios

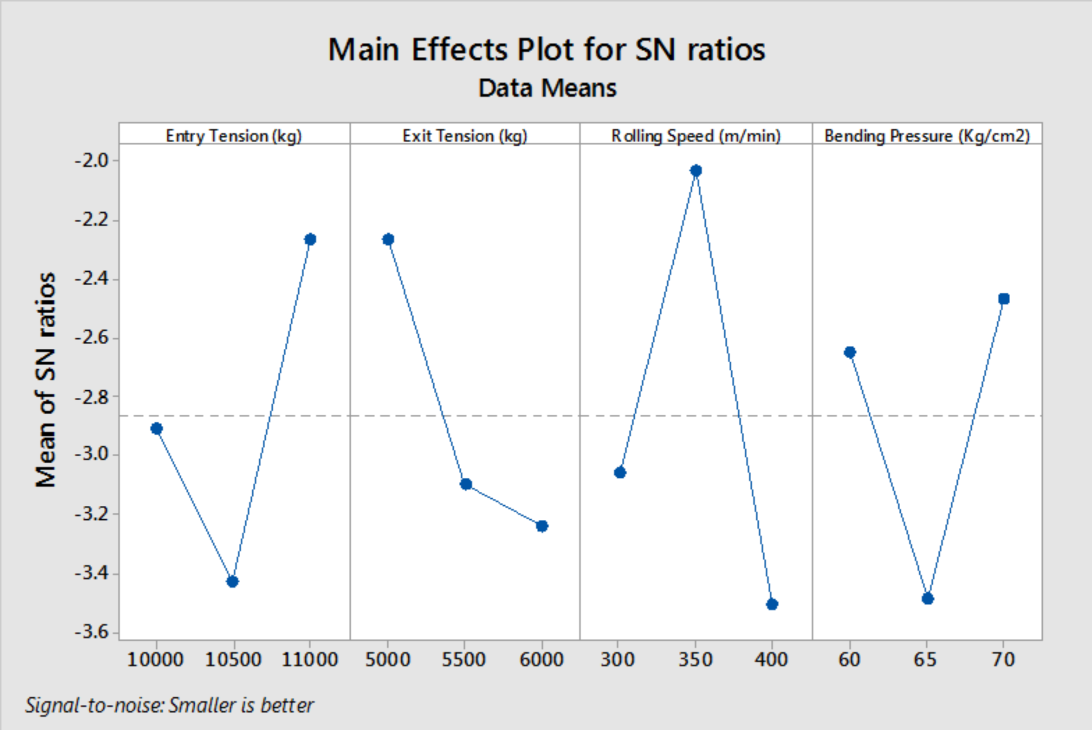
Level	Entry Tension (kg)	Exit Tension (kg)	Rolling Speed (m/min)	Bending Pressure (Kg/cm2)
i	-2.908	-2.262	-3.056	-2.648
ii	-3.425	-3.095	-2.030	-3.485
iii	-2.262	-3.238	-3.509	-2.461
Delta	1.163	0.976	1.479	1.023
Rank	2	4	1	3

Response Table for Means

Level	Entry Tension (kg)	Exit Tension (kg)	Rolling Speed (m/min)	Bending Pressure (Kg/cm2)
1	1.400	1.300	1.433	1.367
2	1.500	1.433	1.267	1.500
3	1.300	1.467	1.500	1.333
Delta	0.200	0.167	0.233	0.167
Rank	2	3.5	1	3.5

Main Effects Graph for Means

Main Effects Graph for a signal-to-noise ratios



The optimum values of factors and their levels are given in the following table

Table: Parameters with their levels	
Parameters	**Optimum Value**
Tension at Exit (Kg)	10500
Tension at Entry (Kg)	6000
Speed of Rolls (mpm)	400
Roll Bending load (Kg/cm^2)	65

- **DOE No 2: Considering rolling parameters such as roller diameter (mm), temperature (ºC), reduction (%), rolling speed (RPM) and their levels**

Table: Factors and levels	
Factors input variables	**Levels**
Roller diameter (mm)	3
Temperature (ºC)	3
Reduction (%)	3
Rolling speed (RPM)	3

Following table shows factors and their levels in Design of Experiment (DOE) No 2

Table: Factors and unit values				
Factors	**Units of Measurement**		**Levels**	
		1	2	3
Roller diameter	(mm)	75	100	125
Temperature	(ºC)	250	300	350
Reduction	(%)	10	20	30
Rolling speed	(RPM)	300	350	400

The below mentioned table shows the measured values of thickness obtained from different experiments.

Table L9 array layout					
Roller Pass No	**Roller diameter**	**Temperature**	**Reduction**	**Rolling speed**	**Exit Thickness of sheet**
1	75	250	10	300	1.3
2	75	300	20	350	1.4
3	75	350	30	400	1.5
4	100	250	20	400	1.2
5	100	300	30	300	1.6
6	100	350	10	350	1.7
7	125	250	30	350	1.4
8	125	300	10	400	1.3
9	125	350	20	300	1.2

For calculating the S/N ratio, smaller-the-better type of control function was used which is the objective function of thickness variation. Calculation and tabulation for S/N ratios and mean of all the experiments were shown as follows.

Table: S/N ratios and mean							
Roller No	**Roller Diameter**	**Temperature**	**Reduction**	**Rolling Speed**	**Exit Thickness of Sheet**	**SNRA3**	**MEAN3**
1	75	250	10	300	1.3	-2.27887	1.3
2	75	300	20	350	1.4	-2.92256	1.4
3	75	350	30	400	1.5	-3.52183	1.5
4	100	250	20	400	1.2	-1.58362	1.2
5	100	300	30	300	1.6	-4.08240	1.6
6	100	350	10	350	1.7	-4.60898	1.7
7	125	250	30	350	1.4	-2.92256	1.4
8	125	300	10	400	1.3	-2.27887	1.3
9	125	350	20	300	1.2	-1.58362	1.2

Response Table for S/ Noise Ratios

Smaller is better

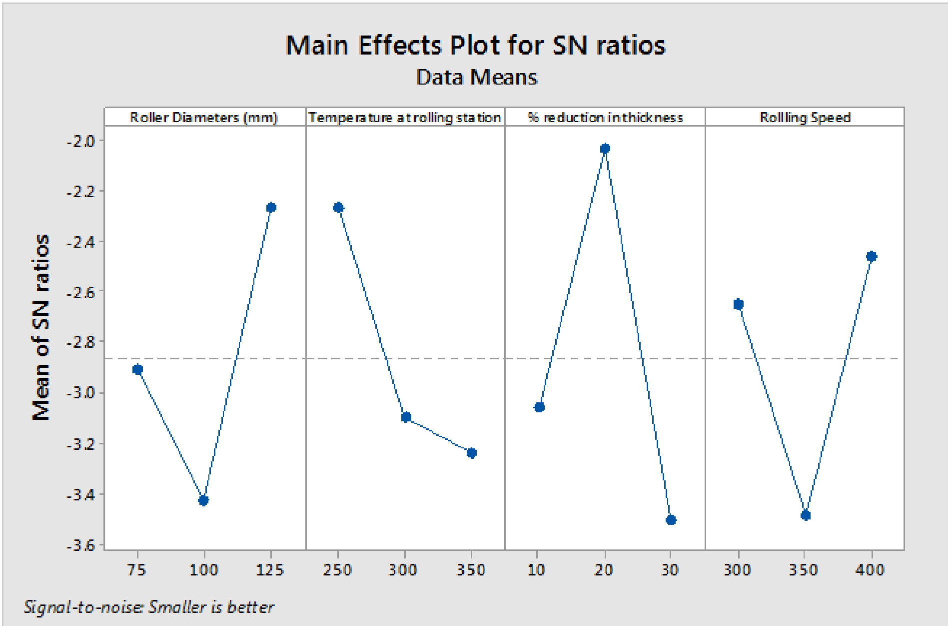
Level	Roller Diameters (mm)	Temperature at Rolling Station	% in	Reduction Thickness	Rollling Speed
i	-2.908	-2.262		-3.056	-2.648
ii	-3.425	-3.095		-2.030	-3.485
iii	-2.262	-3.238		-3.509	-2.461
Delta	1.163	0.976		1.479	1.023
Rank	2	4		1	3

Response Table for Means

Level	Roller Diameters (mm)	Temperature at Rolling Station	% in	Reduction Thickness	Rollling Speed
1	1.400	1.300		1.433	1.367
2	1.500	1.433		1.267	1.500
3	1.300	1.467		1.500	1.333
Delta	0.200	0.167		0.233	0.167

Main Effects Plot for Means

Main Effects Plot for SN ratios



The optimum values of parameters with their levels are given as follows

Table: Optimum values of parameters	
Parameters	**Optimum Value**
Roller diameter (mm)	100
Temperature (°C)	350
Reduction (%)	30
Rolling speed (RPM)	350

Conclusion

Here the Taguchi approach applied for the experimental design of rolling process. To determine the optimum condition for the cold rolling process, a special design of orthogonal arrays and only nine experiments were essential. The results are consistent. With the Taguchi method, design of experiment no (DOE) - 1 conducted; in this experiment- the load at entry, load at exit, speed of rolls & roll bending load are very important to control thickness variation. Taguchi's approach was utilized to study process parameters optimization like roller diameter, temperature, reduction percentage, and rolling speed also. In design of experiment no (DOE) -2 conducted with the Taguchi method has demonstrated that the roller diameter, temperature, percentage reduction & rolling speed are very important to control thickness variation.

References

1. Milan and Zoran et.al, ―Experimental Analysis and Mathematical Modeling of Rolling Force‖, ISSN 0562-1887
2. Jeswiet J., Geiger M., Engel U., Kleiner M., Schikorra M., Duflou J., Neugebauer R., Bariani P., Bruschi S., 2008, ―Metal forming progress since 2000, CIRP Journal of Manufacturing Science and Technology, Vol. 1, No. 1, pp. 2-17.
3. Jahanshahi A.A., Gasthi M.A.H., Mirdamadi S.A., Nawaser K, Khaksar S.M.S., , 2011, Study the effects of customer service and product quality on customer satisfaction and loyalty, International Journal of Humanities and Social Science, Vol. 1 No. 7, pp 253-260.
4. Roy, R.K., 2001, ―Design of Experiments using The Taguchi Approach: 16 Steps to Product and Process Improvement‖. John Wiley & Sons, Inc.
5. Roy, R.K., 1990, ―A Primer on the Taguchi method‖. Competitive Manufacturing Series, Van Nostrand Reinhold, New York.
6. Paralikas, J., Salonitis, K. and Chryssolouris, G., Optimization of roll forming process parameters-a semi-empirical approach, Int J Adv Manuf Technol, 2010, 47:1041–1052.
7. Park, H., Anh T. and Dang, X , An application of ANN-GA Hybrid approach on modelling and optimizing roll forming of aluminium car doorbelt, International Journal of Modern Manufacturing Technologies , 2011, 2067–3604
8. Safdarain, R. and Naeini, H.M., The effects of forming parameters on the cold roll forming of channel section, Thin-walled structure, 2015, 92: 130-136
9. Ji-long,Y. ,Ying-bing ,L. ,Da-yong ,Li.,Ying-hong , P., Simulation of Roll Forming With Dynamic Explicit Finite Element Method, American institute of Physics,2005, CP778 Volume A, Numisheet
10. Serope Kalpakjian, and Steven R. Schmid, Manufacturing Engineering and Technology, 6th ed., Prentice-Hall, 2010. [Google Scholar] [Publisher Link]
11. https://www.chaitanyagrp.com/about-us.html
12. Madhav S Phadke, ―Quality Engineering Using Robust Design‖.
13. Sunil Kumar Shetty, Vidyasagar Shetty et.al, ―Optimization of Rolling Process Parameters using ANOVA and FEM Simulation‖ SSRG International Journal of Mechanical Engineering, Volume 10 Issue 12, 19-24, December 2023
14. Vivek Anil Vaidya, ―Application of Taguchi for Optimization of Process Parameters Inimproving Thickness Variation in Single Stand Cold Rolling Mill‖, International Refereed Journal of Engineering and Science (IRJES) ISSN (Online) 2319-183X, (Print) 2319-1821,
15. Volume 5, Issue 5 (May 2016), PP.15-23
16. Saral Dutta, Hot Rolling Practice – An Attempted Recollection, B. Tech. (Hons.), I.I.T. Executive Director, ISP & RMD, SAIL.
17. A.M. Abrao, B. Denkena, J. Köhler, B. Breidenstein and T. Mörke, (2014), The Influence of Deep Rolling On The Surface Integrity Of AISI 1060 High Carbon Steel, The International Scientific Committee of the ―2nd Conference on Surface Integrity Procedia CIRP 13, 31 – 36.

❑❑❑