Optimization of Physical Properties of Steel Plate using Taguchi Method with Best Combination of Chemical Composition and Mill Process Parameters

Pradeep Kumar Sahu
Assistant Professor, Mechanical Engineering
PCEM, Bhilai-3
Bhilai, India

Prof.Dr.B D Tharakan
Principal
PCEM, Bhilai-3
Bhilai, India

***Abstract*— Taguchi methodology of optimization is employed extensively in several fields. This paper presents the case of Taguchi methodology applied to at one of the rolling method in plate mill, to optimize the standard parameters and output of steel plates. The study is applied at one of the massive scale steel industry of India. The target of the study is to enhance the operational excellence in rolling method with the employment of Taguchi technique. The result shows that, the parameters C, Mn, Si, S, P, Al have an effect on the plate strength. This study helps in improvement of operational excellence in rolling method like production rate, decreased defects and loss because of rejection of defects, and quality of the steel plate.**

***Keywords- Optimization; taguchin technique; s/n ratio; design of experiment; operational excellence; mini-tab 16*.**

I. Introduction

The aim of this paper is study of rolling process and optimization of plate milling process by using Taguchi Method. The focus on this paper is to obtain an optimum process parameter consider as C, Mn, Si, S, P, and Al which provides the optimum value of plate strengths.

The experimentation plan is create at Taguchi's L8 Orthogonal Array (OA) and the software Mini Tab 16 is used to do the analysis of Taguchi Technique to find out the required result. Detail analysis is explained in results and discussion.

Taguchi method of optimization is extensively used in many fields and various research studies are carried out in past. Hence, the rolling process can be optimized by using Taguchi method where plate strengths is important and also depends upon the chemical composition of slab.

In this paper a case study is presented carried out in one of the reputed steel industry of India.

II. Working Of Plate Mill

A plate mill is a reversing mill which reduces the thickness of the heated cast slabs until the final size is achieved.. The material is rolled several times between two heavy rolls in reversing directions. The sequences of operations are: slab reheating, descaling, rolling, levelling, cooling, inspection and shearing. The brief descriptions of these operations are given below.

2.1. Slab reheating: Slab coming from slab yard is reheated in reheating furnaces. These furnaces have heating zone, soaking zone, top and bottom preheating zone, top and bottom heating zone. The soaking zone have flat roof with vertical burners through the roof. The slab move in skid pipes in heating and preheating zones and over a solid hearth in the soaking zone. The slabs are pushed one by one on the charging side roller table.

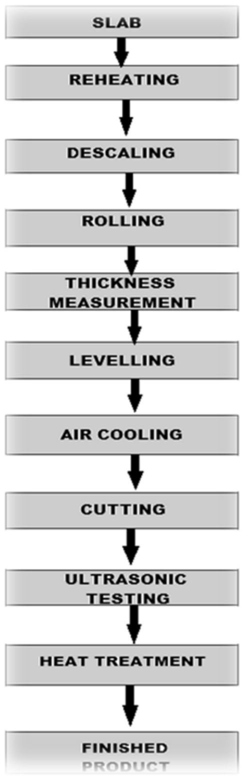

Fig 1 Operational Steps Of Plate Mill

2.2. Hydraulic descaling: Heated slabs are passed through the hydraulic descaler. Here the scale formed during the process of heating will be washed off by means of water spray at a pressure of about 150-170 atm.

2.3. Rolling: The rolling complex consist of one reversible vertical edger, one reversible four high roughing and finishing stand.

A. Vertical edger: The vertical edger placed before the roughing stand help in the production of plate with good edges .This ensures minimum side trimming losses and increases net yield. The vertical edger is driven by two 1800 kW motors placed on top of the stand.

B. Roughing and Finishing stand: They are made of stationery closed top roof housing. These are designed for a maximum rolling force of 4500 Ton. The working rolls of the Roughing and Finishing stands are driven by two 4000 kW and two 6300 kW motors. The maximum speeds of rolling in these stands are 3.5 m/s and 6 m/s respectively. The rolls are pushed in and out by electrically driven carriages.

Heavy plates (41-120mm) are finished in the roughing stand these are cooled and then cut to required size by flame cutting machine.

Lighter plates (7- 40mm) are rolled to the required thickness in the finishing stand.

2.4. Hot crop shear: After rolling the front and the back crop ends are cut using the hot crop shear, which is a cross cut shear with a cutting force of 12.25 MN is of down cut type. The shear can also be used to cut the plate into two pieces by a crop shear.

2.5. Leveling: After hot shearing the plates are leveled, and cut to required widths and lengths. Leveling is done by roller type levelers.

Lighter gauge plates (7- 40mm) cools fast and hence they are leveled at leveler I placed immediately after hot shear.

Heavier gauge plates (21-60mm) do not cool faster and hence these are leveled at leveler-II placed after the hot transfer bed.

2.6. Cooling: After leveling the plates are cooled in grid type cooling beds with special lifting chains. The plates are lifted by these hydraulic lifting chains and are moved along the cooling bed. This ensure scratch free surface of plates.

2.7. Inspection beds: After cooling the plates are transferred to the inspection beds. The inspection beds are provided with tilters so that underside of plates can be inspected easily. Plates having surface defects are rectified by using high frequency grinders.

2.8. Heat treatment*:* As per the requirement of the customer, physical properties is improved by heat treatment

2.9. Testing: The sample of plates taken is tested in Research & Control laboratory. The destructive testing done on the plates are UTS, percentage elongation, impact test, bending and hardness test, while ultrasonic testing is of the non-destructive type.

III. TAGUCHI METHOD

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods and more recently also applied to engineering, biotechnology, marketing and advertising.

Taguchi method is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipments and facilities. These improvements are aimed at improving the desired characteristics and simultaneously reducing the number of defects by studying the key variables controlling the process and optimizing the procedures or design to yield the best result.

Taguchi proposed a standard 8 step procedure for applying his method for optimizing any process:

Step-1: Identify the main function, side effects and failure mode.

Step-2: Identify the noise factors, testing conditions and quality characteristics.

Step-3: Identify the objective function to be optimized.

Step-4: Identify the control factors and their levels.

Step-5: Select the orthogonal array matrix experiment.

Step-6: conduct the experiment.

Step-7: Analyze the data, predict the optimum levels and performance.

Step-8: Perform the verification experiments and plan the future action.

IV. PROBLEM IDENTIFICATION

In plate mill, during rolling process the desired strength of steel may varied due to the chemical composition, while manufacturing process. If desired composition is not obtained before steel plate making it may cause defects also degradation of material take place which lead to loss of economy.

To avoid such kind of problem we need to take care of desired chemical composition of steel slab so that we obtained required grade of chemical composition which may improve the service and economy for these purpose we are obtaining the optimum value the data (plate mill) collected.

From the data C, Mn, Si, S, P, and Al are selected as a chemical composition parameter to get desired value of UTS (ultimate tensile strength), YS (yield strength) and % ELONG (elongation).

V. EXPERIMENT AND DATA COLLECTION

A. Experimental Setup :-

The slab and roller are selected based on the problem identification study.

Roller:

Work material: steel slab

200 x 1300 mm

200 x 1500 mm

250 x 1500 mm

Length from 1800 to 3350mm

B. For Experimental Work :-

To achieve optimum UTS, YS, % ELONGATION by following parameters:

i)	C	iv)	S
ii)	Mn	v)	P
iii)	Si	vi)	Al

C. Planning phase input parameter & there levels for rolling :-

TABLE I. PARAMETER OF THE ROLLING OF STEEL SLAB

Parameters Of The Setting	
Control Factor	**Symbol**
C	Factor A
Mn	Factor B
Si	Factor C
S	Factor D
P	Factor E
Al	Factor F

TABLE II. SELECTED INPUT PARAMETER

Level	C	Mn	Si	S	P	Al
1	0.12	0.71	0.13	0.01	0.017	0.013
2	0.2	1.49	0.33	0.03	0.043	0.029

D. Design of experiments (DOE):-

For selected input parameters experiments are designed using Taguchi L8 orthogonal standard array. For this purpose software Minitab 16.0 is used.

TABLE III. PARAMETERS ARE ARRANGED IN ORTHOGONAL L8 ARRAY

Exp. No.	C	Mn	Si	S	P	Al
1	0.12	0.71	0.13	0.01	0.017	0.013
2	0.12	0.71	0.13	0.03	0.043	0.029
3	0.12	1.49	0.33	0.01	0.017	0.029
4	0.12	1.49	0.33	0.03	0.043	0.013
5	0.20	0.71	0.33	0.01	0.043	0.013
6	0.20	0.71	0.33	0.03	0.017	0.029
7	0.20	1.49	0.13	0.01	0.043	0.029
8	0.20	1.49	0.13	0.03	0.017	0.013

D. Experimentation :-

Taguchi method stresses the importance of studying the response variation using the signal-to-noise (S/N) ratio, resulting in minimization of quality characteristic variation due to parameters. The ultimate tensile strength and yield strength is considered as the quality characteristic with the concept of "the larger-the-better" and % Elongation with the concept of “the smaller the better”. The S/N ratio used for this type response is given by:

The S/N ratio for the larger-the-better is:

S/N = -10*log (mean square deviation)

S/N = -10 log 1/n (Σ1/y2)………… (1)

And for the smaller the better characteristics:

S/N = -10 log 1/n (Σy2)………….. (2)

Where n is the number of measurements in a trial / row, in this case, n=1 and y is the measured value in a run / row. The S/N ratio values are calculated by taking into consideration eqn. 1. The response values measured from the experiments and their corresponding S/N ratio values are listed in table 4.

TABLE IV. RESPONSE VALUES AND S/N RATIO VALUES FOR EXPERIMENTS

S.No.	UTS	YS	%ELONG.	S/N Ratio
1	452	324	26	33.0285
2	480	336	26	33.0321
3	514	367	26	33.0379
4	524	355	25	32.6987
5	478	341	26	33.0327
6	506	356	25	32.6981
7	489	349	27	33.3594
8	483	339	26	33.0327

VI. RESULT

TABLE V.RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS

Level	C	Mn	Si	S	P	Al
1	32.95	32.95	33.11	33.11	32.95	32.95
2	33.03	33.03	32.87	32.87	33.03	33.03
Delta	0.0	0.08	0.25	0.25	0.08	0.08
Rank	**5**	**3**	**2**	**1**	**6**	**4**

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of rolling parameters is the level with the greatest S/N value.

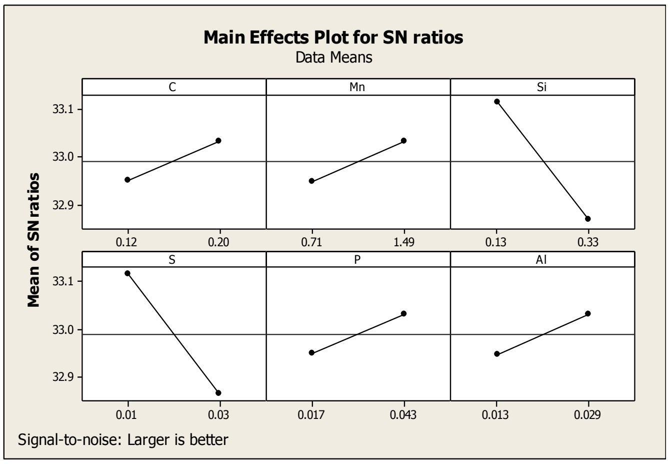

Fig.2 Main Effect plot For S/N Ratios

Based on the analysis of the S/N ratio, the optimal chemical composition obtained at 0.20 C (level 2), 1.49 Mn (level 2), 0.13 Si (level 1), 0.01 S (level 1), 0.043 P (level 2), and 0.029 Al (level 2).

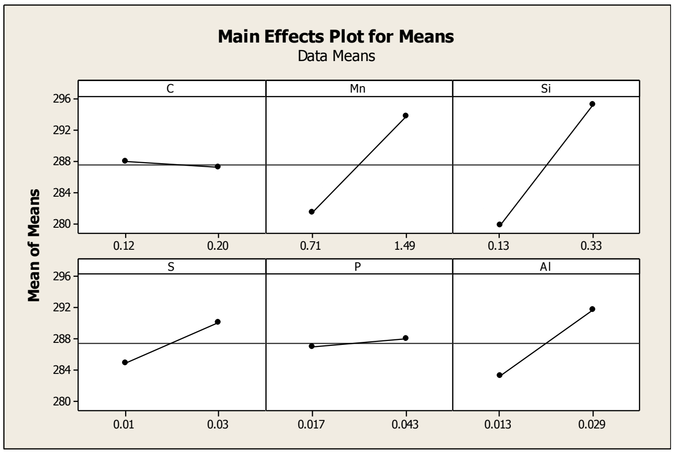

Fig 3. Main Effect plot For Means

VII. CONCLUSION

This paper explains the application of the Taguchi method in the optimization of plate milling operation. From the analysis of the results using the signal-to-noise (S/N) ratio approach, and Taguchi's optimization method, the following can be concluded:

- In this work the effect of chemical composition parameters C, Mn, Si, S, P, and Al are studied on UTS, YS and % ELONG for plate milling operation.
- For UTS, YS and % ELONG. Our observation is based larger is better for s/n ratio.
- From the graph of S-N ratio it can be observed that optimal value of UTS, YS and % ELONG. is obtained at 0.20 C (level 2), 1.49 Mn (level 2), 0.13 Si (level 1), 0.01 S (level 1), 0.043 P (level 2), and 0.029 Al (level 2)..

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