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To Improve the Light Weight Rolling of Merchant Products Using Taguchi Approach

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Abstract: *The massive competition in the world market is to satisfy customer needs; and expectation has triggered the manufacturers to improve the quality and cost of the product. This paper is presented to improve the light weight rolling of merchant products using Taguchi method. Merchant Mill of investigated is a 350 mm finishing mill. The raw material in the form of billets are received and after reheating in the furnaces those are rolled in number of stands to produce angles, channels, rounds and TMT bars of various sizes.*

Light weight rolling is the rolling in prescribed negative limits of tolerance. In other words it is the rolling, amid keeping the weight per unit length below the standard weight per unit length. The product rolled in specified tolerance either positive or negative acquires the same mechanical properties. Light weight rolling is always been of very important concern, because profiles rolled with negative tolerance have always been preferred by the customers as they purchase in tonnage and getting more amount of length is their primary concern which is fulfilled by light weight rolled product.

Light weight rolling leads the manufacturing company to have higher customer satisfaction. Light weight rolling is worthwhile in the following context also, that it offers higher strength to weight ratio, considerable structural saving etc.

Taguchi parameter optimization technique has been applied to mark and optimize the most responsible factors for light weight rolling of merchant products. Taguchi orthogonal array is designed with three factors and three levels. Light weight rolling was considered as the quality characteristic with the concept of "larger-the-better". Optimum rolling parameters with maximum % of light weight rolling has also predicted.

Keywords: *Rolling, light weight, Orthogonal Array, S/N Ratio, Taguchi Method.*

1. INTRODUCTION

Product quality has always been one of the most important aspects of manufacturing operations and so as the customer satisfaction for the manufacturing firms. In view of present global economy and competition, continuous improvement in quality has become a major priority and light weight rolling is one of that kind. The term quality is defined as the totality of features and characteristics that bear on products ability to satisfy a given need. Light weight rolling relates the several dimension of quality including the product performance, features, conformance, durability, reliability, serviceability, aesthetics and perceived quality.

2. TAGUCHI'S PHILOSOPHY

Dr. Genichi Taguchi has developed the statistical concept for quality improvement. Taguchi's method is based upon an approach which is completely different from the conventional practices of quality engineering. His methodology emphasizes designing the quality into product and process, whereas the more usual practice relies upon inspection. Taguchi essentially utilizes the conventional statistical tools but simplifies them by identifying a set of stringent guidelines for experiment layout and the analysis of result. Taguchi philosophy has for reaching consequences founded on very simple three fundamental concepts. These concepts are –

1. Quality should be designed and built into product and not inspected into it.
2. Quality is best achieved by minimising the deviation from the target.
3. The cost of quality should be measured as a function of deviation from the standard and losses should be measured system-wide.

The product design must be so robust that it is immune to the influence of uncontrolled environmental factors on the manufacturing process. Consequently he developed a strategy for quality engineering, called off-line quality control, a three step method consisting of System design, Parameter design and Tolerance design.

System design: The focus of this stage is on determining the suitable working level of control factors. Most often it involves the innovation and knowledge from the application field of science and technology.

Parameter design: This is concerned with determining optimum parameter settings for the products and process. The nominal values of various parameters are specified during this stage. The optimum condition is selected so that the influence of the uncontrolled factors minimum variations in the system performance.

Tolerance design: It is the stage used to fine tune the results of parameter design by tolerance of factor with significant influence on the product thus developing the specification limit for the product. The objective of this stage is to specify the appropriate tolerance about the nominal values established.

Experimental design: In experimental design of the Taguchi approach, the effects of controllable and uncontrollable factors on the product are identified. The methods used for this are complex; they involve the use of factorial design and orthogonal arrays, which reduce the number of experiments required. The use of these methods results in rapid identification of the controlling variables and the ability to determine the best method of process control. The control of these variables sometimes requires major modification to existing process or equipment. For example, variables affecting the light weight rolling can be readily identified and wherever possible the corrections can be specified.

S/N Ratio: Taguchi method is a standardised approach for determining the best combination of the inputs to produce a product or service. In order to minimize the number of tests required Taguchi's experimental design method which uses a special design of orthogonal arrays to study the entire parameter space. He recommends analyzing the variations using an appropriate chosen signal to noise ratio. The S/N ratio measures the sensitivity of the quality characteristics being investigated in a controlled manner to those external influencing factors not under control. The S/N equation depends on the criterion for the quality characteristics to be optimised. While there are different possible S/N ratios, three of them are considered standard and are applicable as per objective.

Calculation of the S/N ratio depends on the experimental objective:

Larger the better

$$S/N_L = -10\log\left(\frac{\sum_{i=1}^{n} 1/y_i^2}{n}\right)$$

e.g. maximum expected life of a component.

Nominal the best

$$S/N_N = 10\log\left(\frac{\bar{y}^2}{s^2}\right)$$

e.g. dimension of a part.

Smaller the better

$$S/N_S = -10\log\left(\frac{\sum_{i=1}^{n} y_i^2}{n}\right)$$

e.g. minimum shrinkage in a cast iron cylinder.
Where n is the number of measurements in a trial, y is observed value in a run, $\bar{y}$ is mean, s^2 is variance.

3. METHODOLOGY

A quick survey was done in the merchant mill to know about the problem of light weight rolling that confers the following things as the outcome, which will be referred as the base course of study for the whole project -

- A typical temperature of billets coming out from the reheating furnace increases the load at the stands and there by constituting to the heavy weight of the section.
- An unwanted sticker mark constituted by the undercooling of roll pass surface hinders the way of getting product with negative tolerance.
- Fast wear out of the roll passes causing thicker web portion in the product mostly influence the light weight of the product.
- Problems due to feeding misalignments as it provides the ground for heavy weight rolled product.

Above survey helped in sorting the influencing factors, that is utilised for the Taguchi method in the methodology.

In accordance with the steps that are involved in Taguchi's Method, a series of experiments are to be conducted. Now, it is started with very first step of the planning phase followed by conducting phase and then analysis in the next chapter.

1. Selection of quality characteristics

Light weight rolling of structurals is the quality characteristic in this project work. Quality characteristic and control factors are purely selected on basis of the survey done. The control factors are the outcome of knowledge and experience of employees working over there. Those significant factors are –

a) Soaking temperature.
b) Rolling rate.
c) Roll cooling.

The factors which have influence on the weight of the product were already mentioned in the fish bone diagram. Above three factors are selected as input for the Taguchi method.

2. Selection of levels and objective function

A minimum of two levels are required to evaluate a factors effect on a given quality characteristics. When multiple levels are utilized the levels should be equally spaced for analytical reasons. These recommendations are apply for levels of continuous factor such as temperature, speed, time etc. (Ranjit K. Roy).

Considering the technological instructions given in the operator's manual provided by the research and control lab 3 levels are selected. Since, the aim is to maximise the % of light weight rolling so the experimental objective selected is Larger the better out of three standard objectives.

Larger the better

$$S/N_L = -10\log\left(\frac{\sum_{i=1}^{n} 1/y_i^2}{n}\right)$$

Where n is the number of measurements in a trial, y is observed value in a run.

3. Selection of appropriate orthogonal array

To select an appropriate orthogonal array for conducting the experiments, the degrees of freedom are to be computed. The same is given below:

Degrees of Freedom: 1 for Mean Value, and

8= (2x4), two each for the remaining.

Total Degrees of Freedom: 9

The most suitable orthogonal array for experimentation is OA_9 array as shown in Table.

Table 3.1: Orthogonal Array (OA_9)

Experiment No.	Control Factors		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

4. CONDUCTING THE EXPERIMENTS

Table below shows the factors and their levels –

Table 3.2: Factors and levels of the experiment

Code	Factors	Levels		
A	Soaking temperature	1220	1250	1280
B	Rolling rate	210	217	224
C	Roll cooling	400	450	500

The quality of the Taguchi Orthogonal Array is that if there is an experiment having 3 factors which have three values, then total number of experiment is 27. Then results of all experiment will give 100% accurate results. In comparison to above method the Taguchi orthogonal array make list of nine experiments in a particular order which cover all factors. Those nine experiments will give 99.96% accurate result. By using this method number of experiments reduced to 9 instead of 27 with almost same accuracy.

Table below shows the experimental layout –

Table 3.3: Experimental layout

Experiment no.	Control factors		
	A(t)	B(r)	C(c)
1	1220	210	400
2	1220	217	450
3	1220	224	500
4	1250	210	500
5	1250	217	400
6	1250	224	450
7	1280	210	450
8	1280	217	500
9	1280	224	400

For the above combinations the sectional weight measured is the mean values of 27 samples for each experiment and is tabulated below -

Table 3.4: Response table

Experiment no.	Control factors			Sectional weight (kg/m)
	A	B	C	
1	1220	210	400	9.622
2	1220	217	450	9.527
3	1220	224	500	9.486
4	1250	210	500	9.437
5	1250	217	400	9.591
6	1250	224	450	9.539
7	1280	210	450	9.497
8	1280	217	500	9.459
9	1280	224	400	9.543

5. ANALYSIS OF OUTPUT RESPONSES

The samples were taken from the rolled product considering to each experiment. Since, the measure for the product to be heavy or light is decided upon the sectional weight of the profile so as the response will be in the form of weight per unit length (kg/m). The mean values of 27 samples are tabulated and are multiplied with the conversion factor to convert into % of light or heavy weight rolled compared to the standard sectional weight.

S/N ratios are calculated based on the objective chosen "larger the best".

Table 4.1: Calculated S/N ratio

Experiment no.	Sectional weight	Difference from standard	% Light	S/N ratio
1	9.622	-0.062		
2	9.527	0.033	0.347	0.349
3	9.486	0.074	0.777	7.351
4	9.437	0.123	1.292	11.767
5	9.591	-0.031		
6	9.539	0.021	0.22	-3.609
7	9.497	0.063	0.662	5.959
8	9.459	0.101	1.061	10.057
9	9.543	0.017	0.179	-5.401

The S/N ratio for the individual control factors are calculated as given below:

St1= (η1+η2+η3), St2= (η4+η5+η6) & St3= (η7+η8+η9)

Sr1= (η1+η4+η7), Sr2= (η2+η5+η8) & Sr3= (η3+η6+η9)

Sc1= (η1+η5+η9), Sc2= (η2+η6+η7) & Sc3= (η3+η4+η8)

For selecting the values of η1, η2, η3 etc. and to calculate St1, St2 & St3 see table 3.1.

ηk is the S/N ratio corresponding to Experiment k.

Average S/N ratio corresponding to soaking temperature at level 1 = Ss1/3

Average S/N ratio corresponding to soaking temperature at level 2 = Ss2/3

Average S/N ratio corresponding to soaking temperature at level 3 = Ss3/3

If j is the corresponding level of each factor, Similarly Srj and Scj are calculated for rolling rate and roll cooling.

The average of the signal to noise ratios is shown in table 4.2. Similarly average S/N ratios can be calculated for other factors.

Table 4.2: Average S/N Ratios for each factor

Level	Soaking temperature		Rolling rate		Roll cooling	
	Sum (Stj)	Avg S/N ratio	Sum (Srj)	Avg S/N ratio	Sum (Scj)	Avg S/N ratio
1	7.7	3.85	17.726	8.863	-5.401	-5.401
2	8.158	4.049	10.406	5.203	2.699	.899
3	10.615	5.307	-1.659	-0.553	29.175	9.725

Below S/N graphs shows the effect of individual factors –

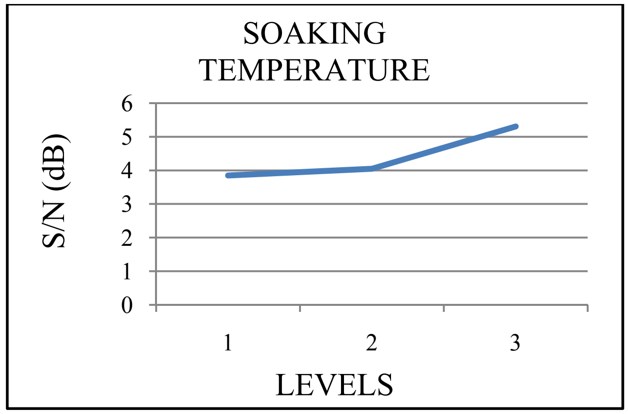

Fig. 4.1: Soaking temperature v_s S/N ratio

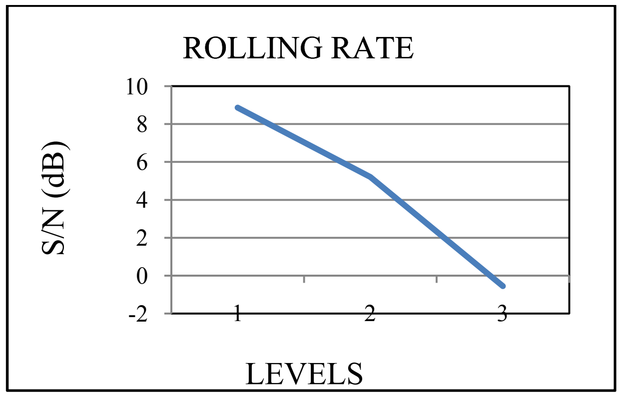

Fig. 4.2 Rolling rate v_s S/N ratio

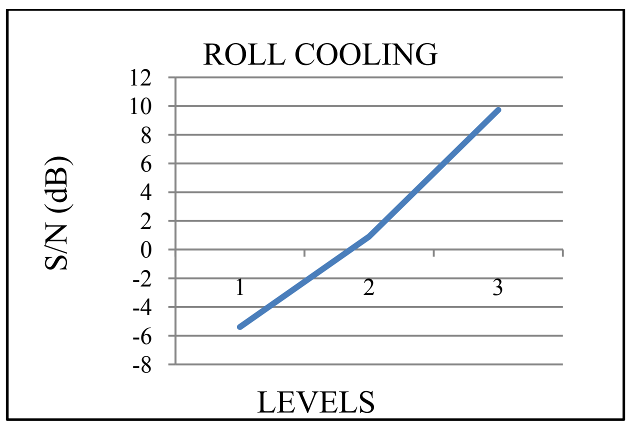

Fig. 4.1 Roll cooling v_s S/N ratio

Optimum values of factors and their levels

Parameter	Optimum Value
Soaking temperature (C)	1280
Rolling Rate (billets/hr)	210
Roll cooling (m3/hr/m2)	500

6. ANALYSIS OF VARIANCE (ANOVA)

The purpose of the analysis of variance (ANOVA) was to investigate which parameters significantly affected the quality characteristic. This is to accomplish by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the design parameters and the error.

Table: ANOVA table

Source	D.O.F	Sum of squares	Mean squares	F ratio	% contribution
A	2	20.22	10.11	1.46	5.44
B	2	117.0	58.5	8.46	31.49
C	2	220.17	110.085	15.92	59.27
error	2	13.822	6.911		3.72
total	8	371.469			100

It is confirmed by ANOVA analysis that roll cooling is most significant contributing 59.27 % to the light weight rolling.

7. CONCLUSION

This paper illustrates the application of the parameter design (Taguchi method) in the optimization of light weight rolling. The following conclusions can be drawn based on the above experimental results of this study:

- Taguchi's Method of parameter design can be performed with lesser number of experimentations as compared to that of full factorial analysis and yields similar results.
- Taguchi's method can be applied for analyzing any other kind of problems as described in this paper.
- It is found that the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for optimizing the process parameters.

REFERENCES

[1] Excerpted from The Certified Quality Engineer Handbook, Third Edition, ed. Connie M. Borror, ASQ Quality Press, 2009, pp. 321–332.

[2] International Journal of control, Automation, and Systems, vol. 5, no. 1, pp. 43-50, February 2007.

[3] K Prasada Rao et al. ISSN: 2250-3676 [IJREST] [international journal of research in engineering science & advanced technology] volume-2, issue-1, 120-129.

[4] International Journal for Quality research UDK-378.014.3(497.11) Short Scientific Paper (1.03).