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OPTIMIZATION OF PROCESS PARAMETERS IN ROLLING OPERATION FOR MANUFACTURING OF THERMOMECHANICALLY TREATED BAR USING MINITAB AND MATLAB SOFTWARE

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ABSTRACT

At low cost, designing high-quality products and process is a challenge to the engineers. For the manufacturing of TMT bars, the critical quality parameter is yield strength. This study aims to choose the optimal variables that will achieve the needed yield strength. In this research work, the use of the Taguchi Method and the concept of DOE (Design of experiment) for optimization of Thermo Mechanical Treatment Process parameter. In the plant, readings have been taken by Taguchi Method and by using MINITAB and MATLAB Software to find optimal combination factors. For optimizing the process parameters ANOVA, S/N ratio (Signal to noise ratio), and orthogonal array have been utilized. Optimum values have been obtained with the help of graphs as well as a confirmation experiment.

Keywords: *Yield Strength, TMT, Control Parameters, S/N Ratio and Taguchi Method*

1. Introduction

In the past, unprocessed iron rods and concrete slabs have been used to construct homes and buildings. [1] The difficulty with this method was that the rods began to corrode sooner than intended. This, in turn, has an impact on the structures' long-term stability, making them dangerous, unstable, and prone to regular maintenance, leaking due to rains, and overall owner dissatisfaction. TMT ("Thermo Mechanically Treated") bars are the solutions to all of the concerns listed above. They are built to meet universal strength, stiffness, and flexibility specifications. TMT bars come in a variety of grades to satisfy the application.

The Taguchi philosophy is founded on three core notions that are both simple and strong. [2] Quality must be built into the product rather than assessed. The greatest way to attain quality is to keep the deviation from the objective as low as possible. The product must be built so that it is impervious to uncontrolled environmental influences.

Quality costs must be calculated as a function of departure from the standard, and losses must be calculated throughout the whole system. One of the most effective Taguchi method strategies is experiment design. The DOE is a set of experiments that will be carried out in order to identify the most relevant factors that influence performance and goal functions. The DOE could demonstrate how to conduct the fewest number of tests while yet obtaining the most crucial data. The DOE method aids in the simultaneous and cost-effective investigation of several parameters (variables). The DOE's most significant procedure in establishing the values of the independent parameters at which a small number of trials would be performed.

2. Literature Review in Brief

TMT bars are an innovation in manufacturing high-strength deformed steel bars for reinforcing materials. Thermomechanical treatment, in which the steel bars are subjected to intense cooling immediately after rolling, is used to achieve increased strength in this procedure. A hardened top layer is formed by a sudden drop in temperature, while the central core remains heated. The heat from the core tempers the cooling in the atmosphere. The bar's strength and ductility are predicted to increase as a result of this treatment. TMT bars combine the best qualities of strength, ductility, bendability, and other desired characteristics. TMT bars are used below half as often as mild steel bars, according to Sandhwar and Roy (2015). Owing to its greater UTS/YS ratio, TMT bars can withstand strong seismic (earth quake prone) loads. When the Fe415 rebar is substituted with the Fe500 rebar, the overall amount of steel used is reduced by 10% to 25%. According to Gaur et al., proper management of the

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ultimate quenching temperature results in optimal strength and a high UTS/YS ratio (2018). According to Roy and Ranjit (2001), today's fundamental rebar criteria are low-rate deformed bars with a 500N/mm2 yield strength and enough ductility for seismic zones. Approximately 55 % to 60 % of India is inside the earthquake zone.

When the rebar is rapidly cooled while passing through a quenching box in the TMT process, the temperature differential causes heat to travel from the core to the surface. Due to the heat remaining in the core after this cycle, the martensite structure of the rebar self-tempers. The austenitic core converts into pearlite as well as ferrite or pearlite ferrite & bainite when the rebar cools further in the cooling bed, according to Ravi Kumar et al. (2015). According to Dean and Edwin (2002), this method boosts yield strength from 150 to 250 Mpa based on cooling conditions.

3. Research Methodology

The yield strength of the rebar is tested using a universal testing machine to study the influence of various conditions on the bar's yield strength. Workpiece material has been IS2830C20 M Mn (C) RC grade of 32 mm dia with C Equivalent to 0.34 Selected. Control factors are selected from the given bar. Taguchi methodology is used for process optimization. Table 1 presents noise factors along with control factors.

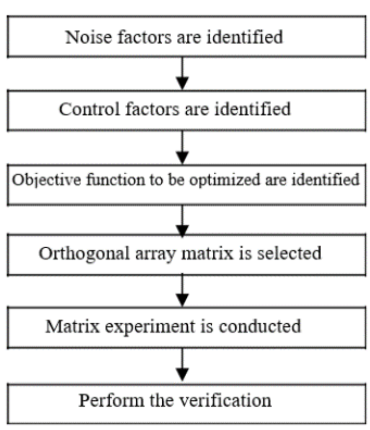


Fig. 1 Steps applied for Optimization

For these experiments, tests on UTM are conducted till they give measurements. Table 2 gives the four control factors and three levels analysed in the experiment. L9 Orthogonal array can be recognized.

Table 1 Control Factor "Affecting Tensile Strength of TMT Bars

Sl. No.	Control Factors	Noise Factors
1.	Tb (Bar Temperature), in^{0}C	Fuel
2.	RS (Rolling Speed), in mps	Energy fluctuations
3.	WP (Water Pressure), in bar	Type of Pump
4.	WQ (Water Flow Rate), in m^3/hr.	Pipe condition"

Table 2 Control Factors and Their Levels

S. No.	Control Factors	Levels 1	2	3
1.	Tb (Bar Temperature)," in^{0}C	1080	1100	1120
2.	RS (Rolling Speed), in mps	6	6.5	7
3.	WP (Water Pressure), in bar	17	18	19
4.	WV (Water Flow Rate), in m^3/hr.	930	960	980

For higher quality attributes, Optimum yield strength is achieved by selecting S/N ratio on bar's tensile strength error, which has minimum error. For S/N ratio, value of η is calculated as:

$$\eta = -10\log10(1/r \sum_{i=1} (1/y_i^2)) \ldots\ldots\ldots\ldots\ldots (1)$$

Where r is the sample size and y_i is the measured yield strength error value.

The S/N ratio of higher the better type is selected and S/N ratio for yield strength variation are computed and represented in Table 3.

4. Experimental Details

The S/N ratio was calculated using a better-type control function since the goal function (optimum yield strength) is greater. Table 3 represents the computed and tabulated S/N ratios for all experiments.

5. Results and Discussions

For every individual control factor, S/N ratio are computed as given below:[3]

Sbt1 = (**η1+ η2+ η3**), Sbt2 = (**η4+ η5+ η6**) & Sbt3= (**η7+ η8+ η9**)

Srs1 = (**η1+ η4+ η7**), Srs2 = (**η2+ η5+ η8**) & Srs3 = (**η3+ η6+ η9**)

Swp1 = (**η1+ η6+ η8**), Swp2 = (**η2+ η4+ η9**) & Swp3 = (**η3+ η5+ η7**)

Table 3 Yield Strength Variation Measured for 32mm TMT Bar with S/N Ratio

Trial	CONTROL FACTORS				YIELD STRENGTH, MPa						S/N
	Tb	RS	WP	WV	1	2	3	4	5	Mean	
1	1	1	1	1	559	562	564	566	568	563.8	55.02
2	1	2	2	2	560	561	563	567	571	564.4	55.03
3	1	3	3	3	558	563	564	566	572	564.6	55.034
4	2	1	2	3	562	564	567	569	571	566.6	55.06
5	2	2	3	1	565	566	568	570	572	568.2	55.08
6	2	3	1	2	568	570	572	574	578	572.4	55.15
7	3	1	3	2	567	568	569	571	577	570.4	55.12
8	3	2	1	3	568	570	576	580	582	575.2	55.19
9	3	3	2	1	570	572	574	576	580	574.4	55.18

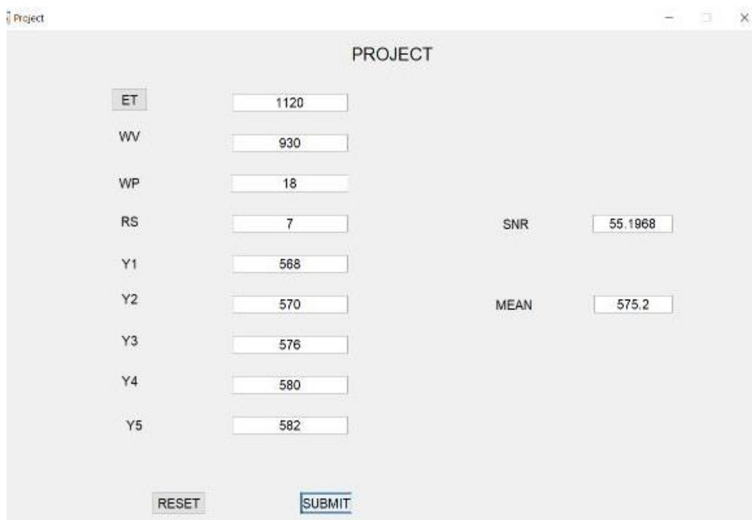


Fig. 2 Signal Noise Ratio have been determined by MATLAB Software

Table 4 Average S/N Ratios for each factor

Level	Bar temperature Tb		Rolling Speed (RS)		Water Pressure (WP)		WATER Flow Rate (WV)	
	Sum (Sbtj)	Avg S/N ratio	Sum (Srsj)	Avg S/N ratio	Sum (Swpj)	Avg S/N ratio	Sum (Swvj)	Avg S/N ratio
1	165.09	55.03	165.2	55.07	165.36	55.12	165.29	55.098
2	165.29	55.10	165.3	55.10	165.28	55.093	165.3	55.10
3	165.49	55.16	165.36	55.12	165.234	55.082	165.284	55.096

Swv1 = (**η1+ η5+ η9**), Swv2 = (**η2+ η6+ η7**) & Swv3 = (**η3+ η4+ η8**)

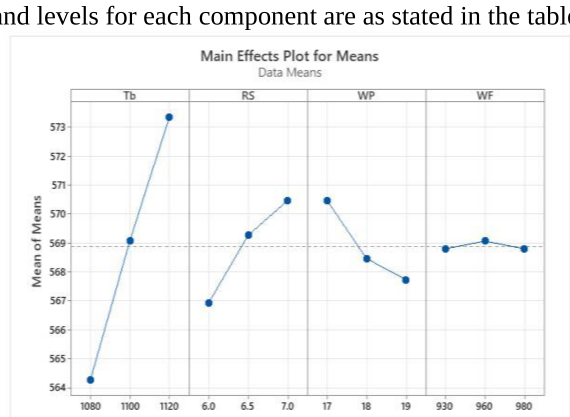
In order to select the η_1, η_2, η_3 etc. values as well as to compute Sbt1, Sbt2 & Sbt3 see Table 3.

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

Average S/N ration corresponding to bar temperature at level 1 = Sbt1/3 Average S/N ration corresponding to bar temperature at level 2 = Sbt2/3 Average S/N ration corresponding to bar temperature at level 3 = Sbt3/3

j is defined as a comparable level for every factor. Likewise, Srsj, Swpj, and Swvj are computed for rolling speed, water pressure, and flow rate. Table 4 shows an average S/N ratio.

These linear graphs show that the best values and levels for each component are as stated in the table.



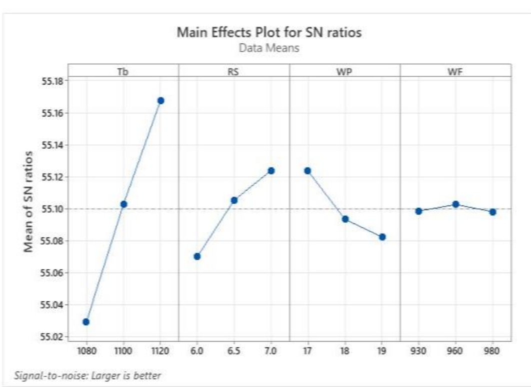


Fig. 3 Graphs for the best values and levels for each component by MINITAB Software

Optimum values of factors and their levels

Parameter Optimum Value

Bar Temperature (0C) 1120

Rolling Speed (mps) 7

Water Pressure (Bar) 77

Water Flow Rate (m3/h)960

Conduct the Verification Experiments

The following table shows the confirmation experiments conducted by setting control aspects Bar Temperature 1120, Rolling Speed (mps) 7, Water Pressure (Bar) 17, Water Flow Rate (m^3/h) 960. All five sets of tests' yield strength (MPa) values were compared and recorded. This shows that the findings are consistent across all of the experiments.

Table 5 Yield strength

Experiment No.	Yield Strength
1	577 MPa
2	579 MPa
3	580 MPa
4	582 MPa
5	583 MPa
Mean	**580.2 MPa**

ANOVA and its Significance

In the orthogonal experiment, (ANOVA is performed in order to determine the magnitude of response in percent for each of the parameters. In order to identify as well as quantify the sources of varied trial outcomes from different trial runs, it is necessary to use this technique.

Table 6 ANOVA results for Yield strength S/N ratio

Parameter	DOF	Adj SS	Adj MS	SS%
BT	2	0.02874	0.01437	79.86
RS	2	0.00446	0.00223	12.4
WP	2	0.00275	0.00137	7.63
WV	2	3.6E-05	1.8E-05	0.1
Error	0	-		
Total	8	0.03599	-	100

This can be noted from the table that for yield strength the contribution of bar temperature (79.86%) and rolling speed (12.40%), water pressure (7.63%) and Flow Rate (0.1%).

6. Conclusion

The use of the Taguchi approach to the optimization of 32mm TMT bar's yield strength of IS2830 C20 M Mn (C) RC is demonstrated in this study. The corresponding C value is 0.34. It has been determined that the bar temperature (Tb), one of the four elements considered, has a large effect on yield strength development, which is a quality attribute. It contributes about 79.86 % to the rise in yield strength.

This indicates that the bar's temperature has a significant impact on the bar's final yield strength.

Bar Temperature (OC) 1120, Water Pressure (Bar) 17, Rolling Speed (mps) 7, Water Flow Rate (m3/h) 960 is found to be the optimal level of process parameters.

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