Studies of Mechanical Characterization of High Strength Deformed Steel Bars

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Abstract*- In modern hot rolling of steel, the rolling speeds are incessantly exaggerated additionally to exaggerated alloy additions. To realize the specified properties, high speed rolling processes should be simulated to review the behaviour modification of varied alloy steels below high strain rate hot deformation conditions. Thermo mechanical treated bar and rod rolling for optimizing rolling parameters in specific Fe-500, 500D and 600, & high alloy steels severally. Property variation with varied carbon in Fe-500 grade steel was investigated through hot Axi isosceles compression tests to live the flow stress of the bar steel samples at varied temperatures and strain rate. Thermo-mechanical simulation studies helped in optimizing the reheating chamber temperatures in bar mill resulting in vital energy saving. Variation in flow behaviour of billets of high Cr-Mo steel between surface and centre thanks to increased piping and segregation was resulting in centre cracks. Modification in extreme temperature plastic deformation behaviour has been investigated victimisation hot deformation studies simulating massive diameter bar rolling in horizontal vertical continuous steelworks.*

Keywords- Deformed steel bars, Thermo mechanical treated bar

I. INTRODUCTION

Corrosion means a loss of an electron of metals reacting with water and oxygen, weakening of iron due to oxidation of the Iron atoms is a well known Example of electrochemical corrosion, this is commonly known as Rust, most structural alloys corrode mainly from exposure to moisture in the air. Corrosion is very dangers, slow deadly killer or enemy of corrosion structure, house, bridges, industry dams, and bridges and builds which where build in fast 10 years in coastal area with area high humidity collapsed. The main cusecs for corrosion is humidity, comes from sea water, bridges, industry emission.[1] The material (Billet) is made through associate integrated steel creating method, exploitation ore treated in Blast furnace, this Blast furnace hot metal further refined in HMDS after that this hot metal converted to steel through BOF & LHF. The chemistry of billets produce in every heat can be precisely controlled with help of spectro meter testing to make the steel resistance the corrosion elements like a Cr, Cu, and P and added in appropriate proportion. [1]

Copper addition: Addition of copper will plug the pores in the rust.

Chromium addition: Addition of Chromium in to steel, increase the passivity of anions, another advantage is we are making the steel slightly ferrite thus pitting resistance is increased, Chromium also increase the passivity and will form an invisible layer. Phosphorous: Phosphorous acts as inhibitor; this will reduce the anodic reaction.

1. The superior corrosion resistance led to longer life.
2. Life Span cost benefit.
3. Due to low carbon content it has high weldability then normal Rebars
4. Due to addition of Copper and Chromium, the natural ductility of steel is enhanced making the Rebars more flexible, this allows more tolerance against the breakage of Rebars providing longer life to the structure.
5. High Yield Strength couples with good ductility and bendability.
6. Improve Fire Resistance.
7. CRS rebar may not require extra precaution during material handle, storage and welding.
8. Increased life expectancy of Structures 1.5 to 1.7 times compared to normal TMT rebar.
9. During fabrication no maintenance.
10. Workable area is very poor conditions.
11. Applicable for Seismic Zone

II. EXPERIMENTAL

The Billet is created through an integrated steel creating method, exploitation ore treated in Blast furnace, this Blast furnace hot metal further refined in HMDS after that this hot metal converted to steel through BOF & LHF.

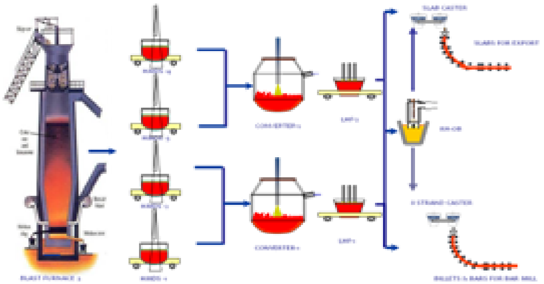


Fig 2.1: STEEL MAKING FACILITIES

2.1 JSW - BAR ROD MILL MANUFACTURING EQUIPMENTS

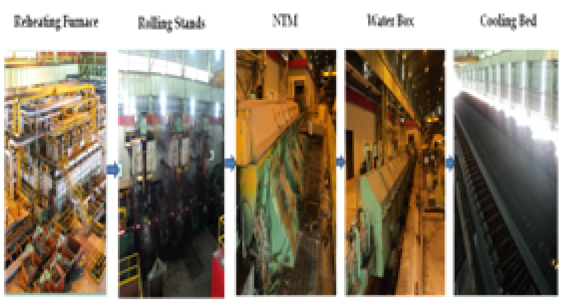


Fig 2.2: BAR ROD MILL MANUFACTURING EQUIPMENTS

The integrated steelworks Billet is later on hot rolled through an automatic 22 stand rolling mill; the recent rolled bars area unit treated with the on-line thermo mechanical treatment through the subsequent method,

2.2 MECHANICAL TESTING

Tensile Test: Machine type - Computerized universal testing machine- 100 ton - imported Taiwan and 12mm to 40mm TMT Rebars sizes cane be testing in machine.

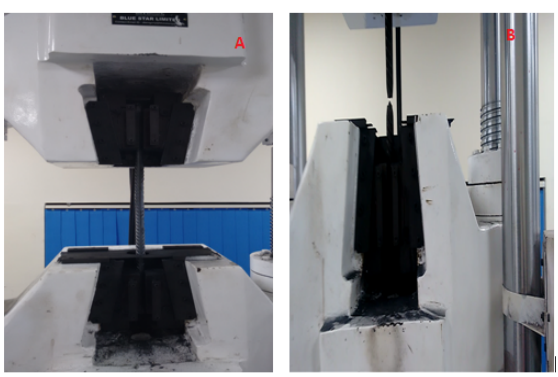


Fig 2.3: Tensile Test

Bend and Rebend machine: Supplier - CHAINI, BLUE STAR LIMITED Machine type - HEAVE DUTY BEND AND REBEND TESTING MACHINE and 12mm to 40mm TMT Rebars sizes cane be testing in machine.

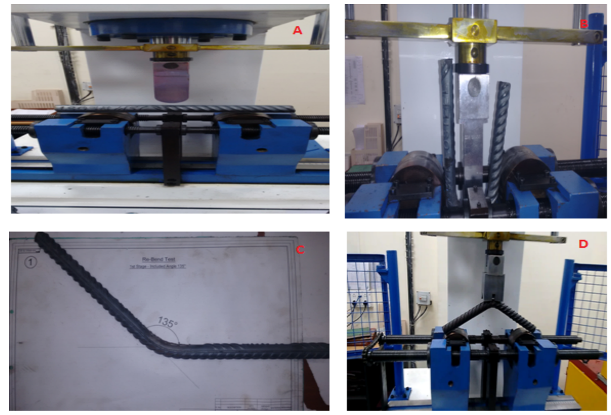


Fig 2.4: Bend and Rebend machine

III. RESULT AND DISCUSION

MICROSTRUCTURE

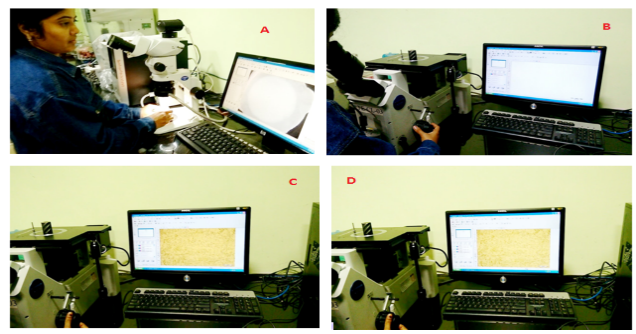


Fig 3.1: OLYMPUS MACHINE

FE 600 CRS

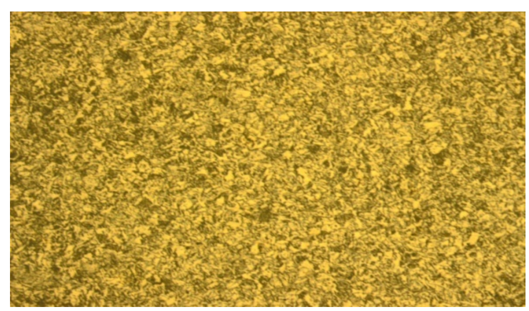


Fig 3.2A: 500X

FE 500D CRS

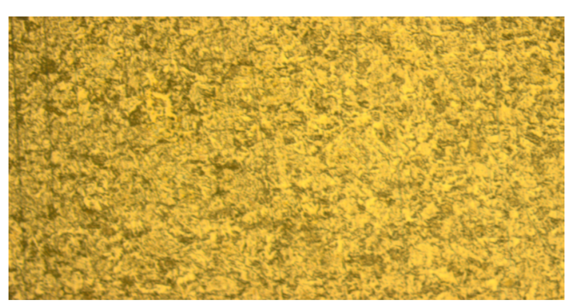


Fig 3.2B: 500X

Take the metal sample which needs to be polished and of which the microstructure needs to be seen. Place the sample in the abrasive cutting machine for sample cutting. Cut the sample of length one inch. Then the sample is washed in water and polished in the polishing cloth with diamond paste of size 1micron. The sample is polished until mirror finish is obtained and then washed in water. Then the sample is etched or dipped with NITAL solution (10% HNO3 in Ethanol) until a clear ring structure/ microstructure is seen and then it is immediately dried, after checking the microstructure in sample piece.

Table 1.1: DENSITY CALCULATION

	25MM				
	Wt/meter	Core dia	Rib length	Rib height	Ar Value
Fe 500D CRS	3.832	24.24	47.6	2.04	**6.744**
Fe 600 CRS	3.857	24.16	46.9	2.01	**6.547**

Two 600 to 700 mm length samples to be collected after rolling the first bar, one sample will be tested for weight/meter conformation. Another sample will be tested for mechanical properties.

Table 1.2: CONTROL & NOISE FACTORS

Sr.No	Process Parameter	Unit	Codes	Level 1	Level 2	Level 3	Level 4	Level 5
1	F/C Exit Temperature	(^{0}C)	A	1080	1085	1090	1098	1111
2	Mill Speed	(m/s)	B	11.5	12	12.5	13	13.5
3	Water Flow	(LPM)	C	19880	20560	22524	22683	22652
4	Water pressure	(Bar)	D	13.5	14.1	15.1	15.5	16.1
5	Billet Temperature	(^{0}C)	E	1019	1030	1035	1075	1080
6	Cooling Bed Entry temperature	(^{0}C)	F	560	565	570	575	580

In Taguchi technique, the term 'signal' represents the fascinating value (mean) for the output characteristics and additionally the term 'noise' represents the undesirable value for the output characteristics. It permits effecting modelling and analysis of the influence of method variables on the response variables. This improvement technique is dispensed during a 3 stage approach reminiscent of system style, parameter style and tolerance style.

Table 1.3: L25 ORTHOGONAL ARRAY

Sr.No	A	B	C	D	E	F
01	1	1	1	1	1	1
02	1	2	2	2	2	2
03	1	3	3	3	3	3
04	1	4	4	4	4	4
05	1	5	5	5	5	5
06	2	1	2	3	4	5
07	2	2	3	4	5	1
08	2	3	4	5	1	2
09	2	4	5	1	2	3
10	2	5	1	2	3	4
11	3	1	3	5	2	4
12	3	2	4	1	3	5
13	3	3	5	2	4	1
14	3	4	1	3	5	2
15	3	5	2	4	1	3
16	4	1	4	2	5	3
17	4	2	5	3	1	4
18	4	3	1	4	2	5
19	4	4	2	5	3	1
20	4	5	3	1	4	2
21	5	1	5	4	3	2
22	5	2	1	5	4	3
23	5	3	2	1	5	4
24	5	4	3	2	1	5
25	5	5	4	3	2	1

Based on taguchi method an orthogonal array (OA) is considered to determine the optimal yield strength for FE 600D. The experiment was carried out to analyze the process parameters on yield strength of FE 600D. The experimental arrange was developed by considering six parameters and 5 levels supported Taguchi technique. F/C Exit Temperature (A), Mill Speed (B), Water Flow (C), Water pressure (D), Billet Temperature (E) and Cooling Bed Entry temperature (F) are the process parameters are considered for the study. [2]

Table 1.4: COMBINATION OF PARAMETERS IN (L25) ORTHOGONAL ARRAY

Sr.No	F/C Exit Temp (^{0}C)	Mill Speed (m/s)	Water Flow (LPM)	Water pressure (Bar)	Billet Temp (^{0}C)	Cooling Bed Entry temp (^{0}C)	Yield Strength (N/mm^2)	S/N Ratio (db)
01	1080	11.5	19880	13.5	1019	560	646	56.2047
02	1080	12.0	20560	14.1	1030	565	603	55.6063
03	1080	12.5	22524	15.1	1035	570	655	56.3248
04	1080	13.0	22683	15.5	1075	575	647	56.2181
05	1080	13.5	22652	16.1	1080	580	621	55.8618
06	1085	11.5	20560	15.1	1075	580	651	56.2716
07	1085	12.0	22524	15.5	1080	560	651	56.2716
08	1085	12.5	22683	16.1	1019	565	645	56.1912

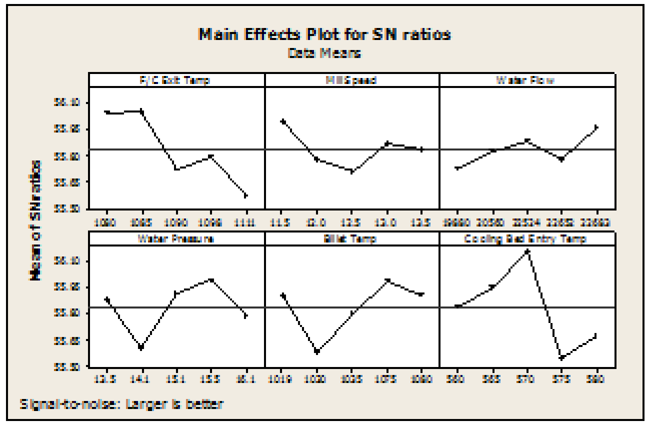
09	1085	13.0	22652	13.5	1030	570	640	56.1236
10	1085	13.5	19880	14.1	1035	575	588	55.3875
11	1090	11.5	22524	16.1	1030	575	585	55.3431
12	1090	12.0	22683	13.5	1035	580	604	55.6207
13	1090	12.5	22652	14.1	1075	560	594	55.4757
14	1090	13.0	19880	15.1	1080	565	624	55.9037
15	1090	13.5	20560	15.5	1019	570	650	56.2583
16	1098	11.5	22683	14.1	1080	570	648	56.2315
17	1098	12.0	22652	15.1	1019	575	598	55.5340
18	1098	12.5	19880	15.5	1030	580	582	55.2985
19	1098	13.0	20560	16.1	1035	560	612	55.7350
20	1098	13.5	22524	13.5	1075	565	642	56.1507
21	1111	11.5	22652	15.5	1035	565	624	55.9037
22	1111	12.0	19880	16.1	1075	570	618	55.8198
23	1111	12.5	20560	13.5	1080	575	580	55.2686
24	1111	13.0	22524	14.1	1019	580	584	55.3283
25	1111	13.5	22683	15.1	1030	560	597	55.5195

The levels of these parameters chosen for experimentation are given in the Table 1. An L25 orthogonal array was chosen (Table 2) for statistical analysis. [7] The experiments were conducted supported the run order generated by Taguchi technique and also the results were obtained. This analysis includes the rank supported the delta statistics, that compares the relative price of the results. The experimental results were reworked into S/ N ratios. [7]

Table 1.5: RESPONSE TABLE FOR S/N RATIO

Level	F/C Exit Temp	Mill Speed	Water Flow	Water Pressure	Billet Temp	Cooling Bed Entry Temp
1	56.04	55.99	55.72	55.87	55.90	55.84
2	56.05	55.77	55.83	55.61	55.58	55.95
3	55.72	55.71	55.88	55.91	55.79	56.15
4	55.79	55.86	55.78	55.99	55.99	55.55
5	55.57	55.84	55.96	55.79	55.91	55.68
Delta	0.48	0.28	0.23	0.38	0.41	0.60
Rank	2	5	6	4	3	1

The S/N quantitative relation for the yield strength victimisation 'larger the better' characteristics, which may be calculated as power transformation of the loss perform is given as. [7]



Graph 1: MAIN EFFECTS PLOT FOR SN RATIOS – YIELD STRENGTH

In Taguchi technique, the term "signal" represents the fascinating worth (mean) for the output characteristics and also the term "noise" represents the undesirable worth for the output characteristics. Taguchi uses S/N magnitude relation to live the standard characteristics deviating from the required worth. [6]

Table 1.6: ANALYSIS OF VARIANCE FOR CRS

Source	DF	Seq SS	Adj SS	Seq MS	F	P	Contribution
F/C Exit Temp	4	4473.36	4473.36	1118	0.81	0.577	26.84%
Mill Speed	4	1111.36	1111.36	278	0.20	0.925	6.67%
Water Flow	4	850.96	850.96	213	0.15	0.951	5.1%
Water Pressure	4	2182.16	2182.16	546	0.40	0.804	13.09%
Billet Temp	4	2544.56	2544.56	636	0.46	0.763	15.27%
Cooling Bed Entry Temp	4	5001.44	5001.44	1375.44	0.94	0.454	30.01%
Error	**0**	**500.32**	**500.32**				**3.02%**
Total	**24**	**16664.16**					**100%**

Statistically, F take a look at tool is performed to envision that style parameters have a big impact on the standard characteristic. The F-ratio may be a magnitude relation of the mean sq. error to the residual error and is historically accustomed verify the many of an element. The P-value reports the many level (suitable and unsuitable) in Table five, proportion of contribution is outlined because the significance rate of method parameters on the yield strength. [6]

Table 1.7: OPTIMUM LEVEL PROCESS PARAMETERS FOR YIELD STRENGTH

Sr.No	**Material**	F/C Exit Temperature (^{0}C)	Mill Speed (m/s)	Water Flow (LPM)	Water pressure (Bar)	Billet Temperature (^{0}C)	Cooling Bed Entry temperature (^{0}C)	Yield Strength (N/mm^2)	S/N Ratio (db)
01	**CRS**	1080	12.5	22524	15.1	1035	570	655	56.3248

A statistical regression model is employed to develop victimization applied math code 'MINITAB 16'. This model offers the correlation between the effective factors (F/C Exit Temperature (A), Mill Speed (B), Water Flow (C), Water pressure (D), Billet Temperature (E) and Cooling Bed Entry temperature (F)) and the yield strength (quality characteristic) to observed data.

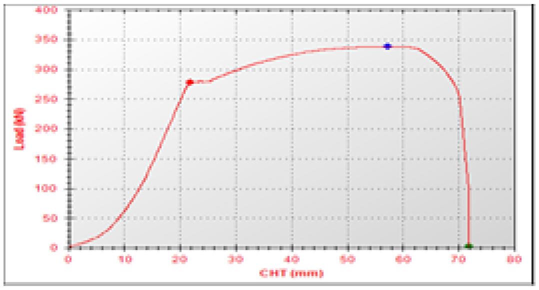
Table 1.8: TENSILE RESULTS

Fe 500D CRS		**Fe 600 CRS**	
INPUT DATA		**INPUT DATA**	
Specimen Shape	**Solid Round**	Specimen Shape	**Solid Round**
Specimen Type	**Mild Steel**	Specimen Type	**Mild Steel**
Specimen Diameter (mm)	**24.82**	**Specimen Diameter (mm)**	**24.93**
Initial G.L. For % elong **(mm)**	**125**	Initial G.L. For % elong **(mm)**	**125**
Pre Load Value **(KN)**	**0**	Pre Load Value **(KN)**	**0**
Max. Load **(KN)**	**1000**	Max. Load **(KN)**	**1000**
Specimen Cross Section Area **(mm2)**	**314.159**	Specimen Cross Section Area **(mm2)**	**488.089**
Final Sp Diameter **(mm)**	**17**	Final Sp Diameter **(mm)**	**17.48**
Final Gauge Length **(mm)**	**123**	Final Gauge Length **(mm)**	**147**
Final Area **(mm2)**	**226.98**	Final Area **(mm2)**	**242.73**
OUTPUT DATA		**OUTPUT DATA**	
Load At Yield **(KN)**	**277.428**	Load At Yield **(KN)**	**319.29**
Elongation At Yield (mm)	**21.790**	**Elongation At Yield (mm)**	**24.810**
Yield Stress (N/mm2)	**573.168**	**Yield Stress (N/mm2)**	**654.163**
Tensile Strength (N/mm2)	**697.501**	**Tensile Strength (N/mm2)**	**750.416**
% Elongation (%)	**18.39**	**% Elongation (%)**	**17.60**
Load at Peak **(KN)**	**337.608**	Load at Peak **(KN)**	**366.270**
Elongation at Peak **(mm)**	**57.370**	Elongation at Peak **(mm)**	**44.880**
Elongation At Break **(mm)**	**71.890**	Elongation At Break **(mm)**	**55.220**
% Reduction Area **(%)**	**52.22**	% Reduction Area **(%)**	**50.27**

After rupture of specimen stop the pump motor. Shut the proper management valve, & take away the broken items of check piece & then operate left management valve to require down the piston, place final gauge length and final military intelligence. All data like YS, UTS & %Elongation will display and record into the system (PC connected to UTM), MES and Test report.

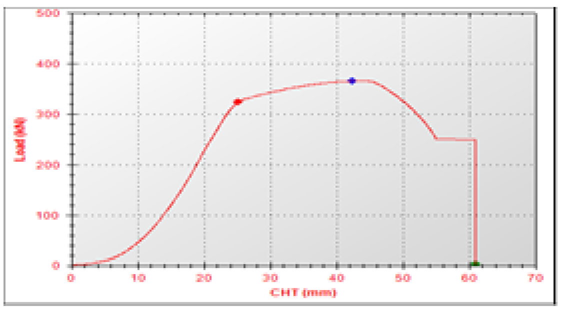
After rupture of specimen stop the pump motor. Shut the proper management valve, & take away the broken items of check piece & then operate left management valve to require down the piston, place final gauge length and final military intelligence. All data like YS, UTS & %Elongation will display and record into the system (PC connected to UTM), MES and Test report.

FE 500D CRS



Graph 1.2A: Fe 500D CRS

FE 600 CRS



Graph 1.2B: Fe 600 CRS

Table 1.9: CHEMICAL COMPOSITION

Fig 3.3: CHEMICAL COMPOSITION RESULT

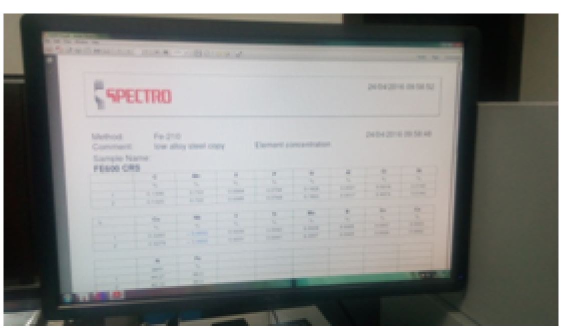


Fig 3.4: CHEMICAL COMPOSITION RESULT

The online Steel making samples will be received in the form of round shape. These samples are taken at various stages of steel making. As per the analysis reports from the laboratory the operations decides the additions of raw materials and further processing, The test samples are transferred to spectrometer room with number displaying board. The associate chemist/shift chemist will place the milled/polished surface of the sample on the sparking stand of the spectrometer and select the start button. Analysis process takes place and the results are displayed on the screen. 2~3 sparks are taken till concurrent readings are observed. For concluding the concurrent readings range as in Annexure-A is followed.

Table 1.9: CHEMICAL ANALYSIS REPORT

Chemical Analysis Report of BRM#2 Samples.

Sample Details	C %	Mn %	S %	P %	Si %	Al T %	Cr %	Ni %	Cu %	Nb %	V %	Ti %	Mo %	B %	Sn %	Ca %
FE 600 CRS	0.131	0.73	0.009	0.078	0.182	0.002	0.501	0.014	0.328	0.001	0.001	0.001	0.001	0.0005	0.001	0.0002
FE 500D CRS	0.129	0.69	0.022	0.077	0.182	0.002	0.502	0.013	0.268	0.001	0.001	0.001	0.001	0.0006	0.001	0.0007

NOTE: The analysis pertains to the given samples only.

Table 1.10: QUANTITY OF MATERIAL LOST IN DIFFERENT CORROSION ENVIRONMENT

		FE 500D CRS			FE 600D CRS		
Sr.No	**No. of days**	**Initial weight**	**Final weight**	**% of weight loss**	**Initial weight**	**Final weight**	**% of weight loss**
01	1	3.832	3.83	0.052	3.857	3.855	0.052
02	5	3.832	3.82	0.313	3.857	3.845	0.311
03	10	3.832	3.80	0.835	3.857	3.800	1.478
04	15	3.832	3.77	1.618	3.857	3.750	2.774
05	20	3.832	3.70	3.445	3.857	3.721	3.526
06	25	3.832	3.61	5.793	3.857	3.700	4.071
07	30	3.832	3.50	8.664	3.857	3.650	5.367

The weight loss methodology is employed to seek out the speed at that the fabric is obtaining depleted in corrosive media. For this, corrosive media specifically Salt spray tests Marine water containing NaCl answer were taken and also the substrates were immersed in corrosive media severally for No. of days. Then the substrate was removed, washed with H2O and dried at temperature. The amendment in weight of the substrates was measured, from that the share of fabric loss is calculated.

IV. CONCLUSION

1. Cooling Bed Entry Temp (30.01%) has the highest influence on yield strength followed by F/C Exit Temp (26.84%), Billet Temp(15.27%), Water pressure (13.09%), Mill speed (6.67%) and water flow (5.1%) for FE 600D.
2. The Bend and Rebend tests were carried out for visualization for cracks.
3. Formation of Marten site ring in FE 600 CRS is better than Fe 500D CRS.
4. Increase in marten site ring increases the rate of elongation and decreases the UTS/YS ratio.
5. The density of FE 600D is little bit more than the FE 500D.
6. The optimal tensile test combination for maximum yield strength is found to be $A_1B_3C_3D_3E_3F_3$ for FE 600D.
7. Based on the results, the weight loss method shows that the FE600D perform better corrosion resistance than the FE 500D.

V. SCOPE FOR FUTURE WORK

1. The yield strength can be improved further by increasing the Mn, Cr and Cu percentage.
2. The scratch wear test can be done for Fe 600 CRS.

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