INCREASING MILL UTILIZATION FOR BETTER OEE

Name: Ashwini Kumar Biswal
Branch: Mechanical Engineering
Department: Wire Rod Mill
College: IIT Kharagpur

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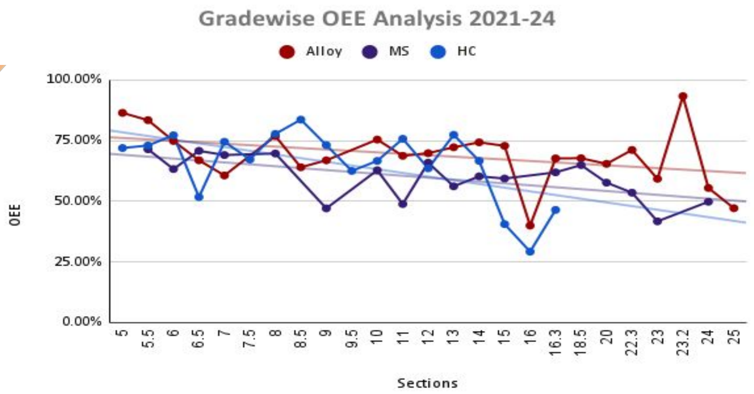
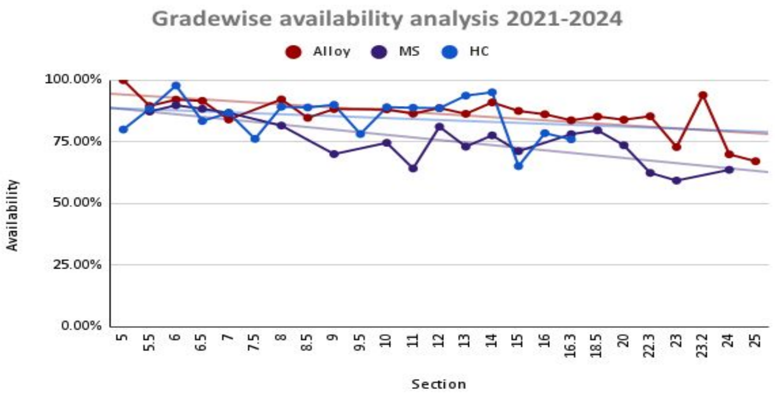
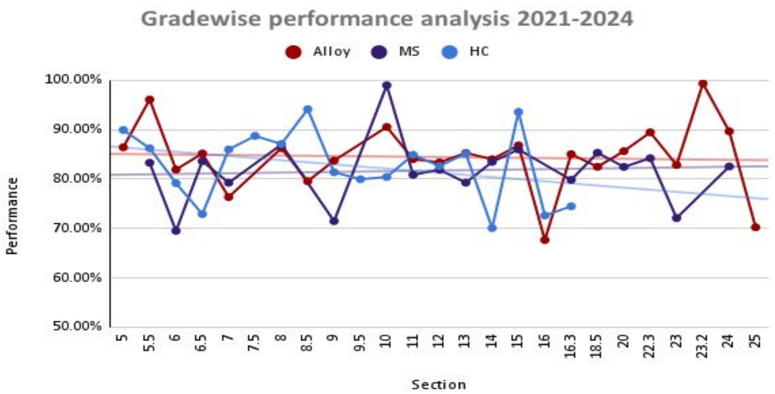
Preface







0.982 MTPA

Production at WRM JSP Patratu 2022-2024

62.28%

OEE at WRM JSP Patratu 2022-2024

74.16%

Availability at WRM JSP Patratu 2022-2024

87.37%

Performance at WRM JSP Patratu 2022-2024

100%

Quality at WRM JSP Patratu 2022-2024

This project aims to increase mill utilization and improve Overall Equipment Effectiveness (OEE) of WRM JSP Patratu. OEE is the product of three parameters that are Availability, Performance, and Quality. Availability is total hot hours by available time. While Performance is actual production by rated production. Quality is prime production by total production. Recognizing the gap between ideal and actual production scenarios, the project seeks to minimize losses through Total Productive Maintenance (TPM) and Lean manufacturing methods like Six Sigma and World Class Manufacturing, at the same time aims to reduce downtime. By addressing equipment malfunctions, process inefficiencies, and resource constraints, we strive for significant improvements in efficiency and productivity. Above is the presentation of the grade wise variation of the different parameters of OEE with the sections for the year 2021-24, which gives some valuable insights which are discussed below.

Company Overview

About JSP

Jindal Steel and Power (JSP) is a leading Indian steel and energy company, part of the OP Jindal Group. Founded in 1952, JSPL has grown to become one of India's top steel producers, with operations spanning across steel manufacturing, power generation, mining, and infrastructure. The company is known for its innovative and sustainable practices, contributing significantly to India's industrial growth and infrastructure development. JSPL's commitment to excellence and cutting-edge technology has established it as a key player in the global steel and power industry.

About JSP Patratu

JSP Patratu is a 1.6 MTPA steel plant. Wire Rod Mill (0.6 MTPA) and Bar Rod MIll (1 MTPA) are the major units with Producer Gas Plant, Rebar Service Centre, Brick Plant and Mill Utility as the subsidiary units.

Future of JSP Patratu

The future of JSP Patratu is promising with Industry 4.0, automation, machine learning, artificial intelligence, and improved data management enhancing efficiency, productivity, and operational excellence.

History

Origin

Traditionally, data logging, quality checking, and Stelmor Conveyor operations in wire rod mills rely on manual record-keeping and periodic inspections. Operators refer to previous logs and trial-and-error methods to set parameters like conveyor speed and laying head temperature. Quality checks involve visual inspections, sample testing, and manual measurements to assess properties like hardness and tensile strength. Stelmor Conveyor operations depend on experienced operators to adjust cooling rates and ensure uniformity, often compensating for equipment wear and tear through adjustments and maintenance based on historical performance data.

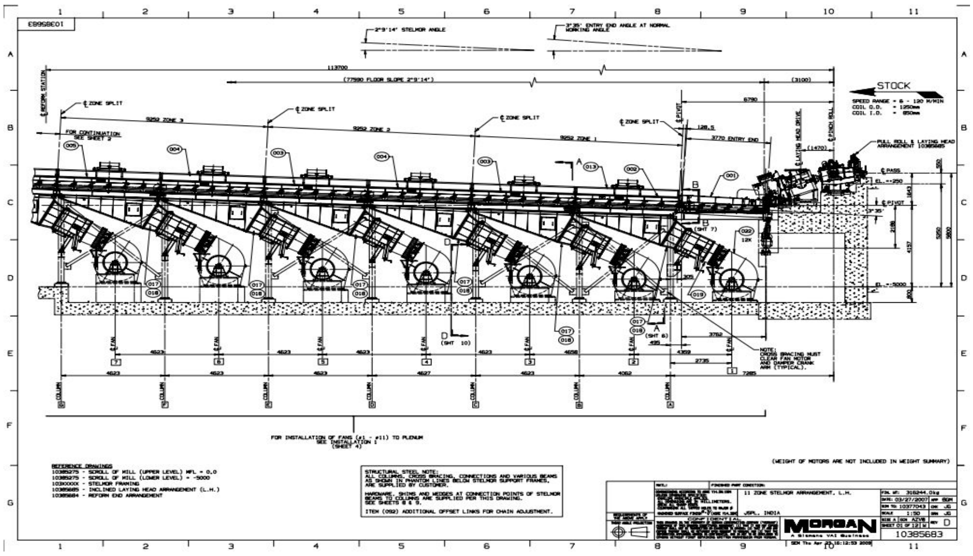
Current Developmental status

Currently, advancements in data logging, quality checking, and Stelmor Conveyor operations in wire rod mills have introduced automated systems and real-time monitoring. Modern sensors and IoT devices now collect and analyze data continuously, providing precise control over parameters like conveyor speed and temperature. Improved cooling techniques, such as advanced perforation designs and enhanced blower systems, ensure more uniform cooling and higher product quality. Machine learning and AI are being implemented to predict and optimize microstructure transformations, reducing reliance on manual adjustments and historical data. These technological improvements lead to higher efficiency, consistent product quality, and reduced operational downtime.

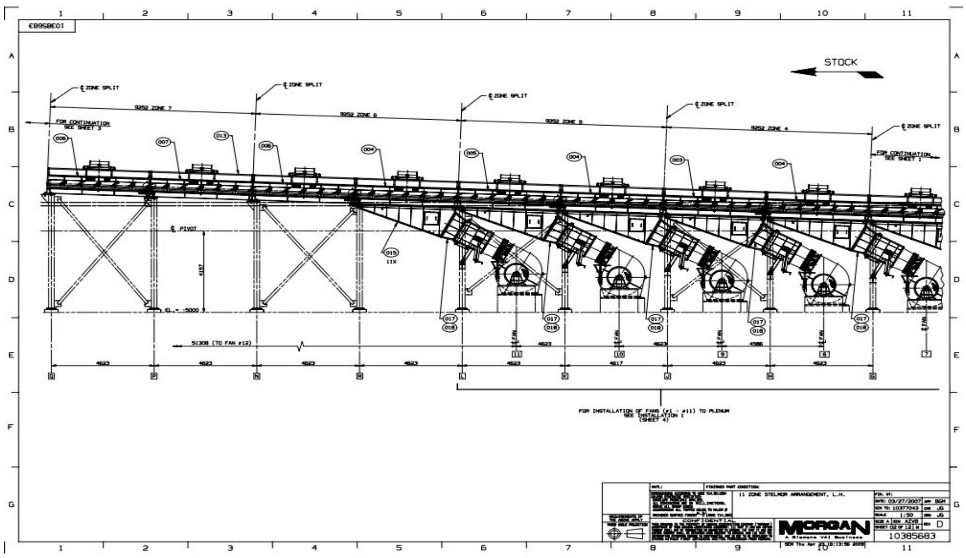
Research

1. Opportunities near the Stelmor Conveyor

Stelmor Conveyor arrangement at JSP Patratu



Region 1



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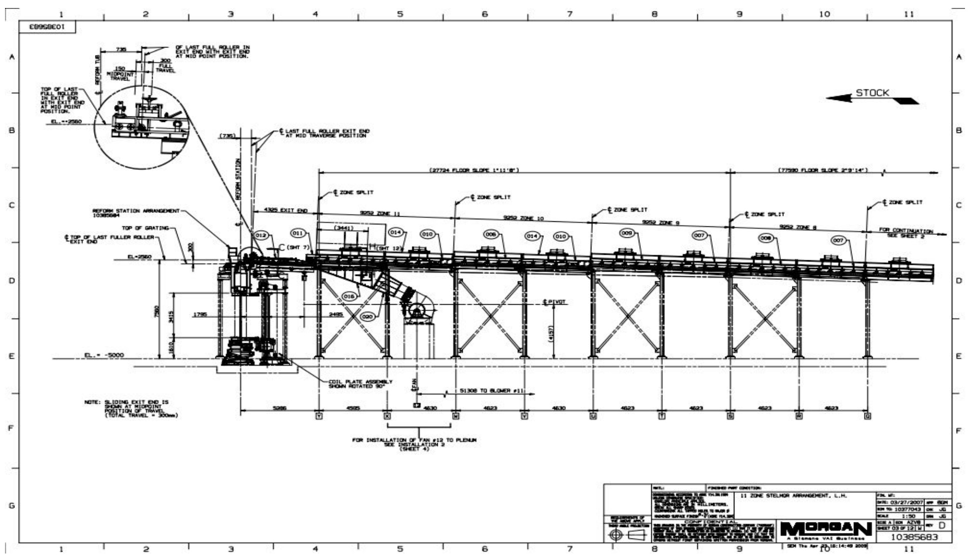
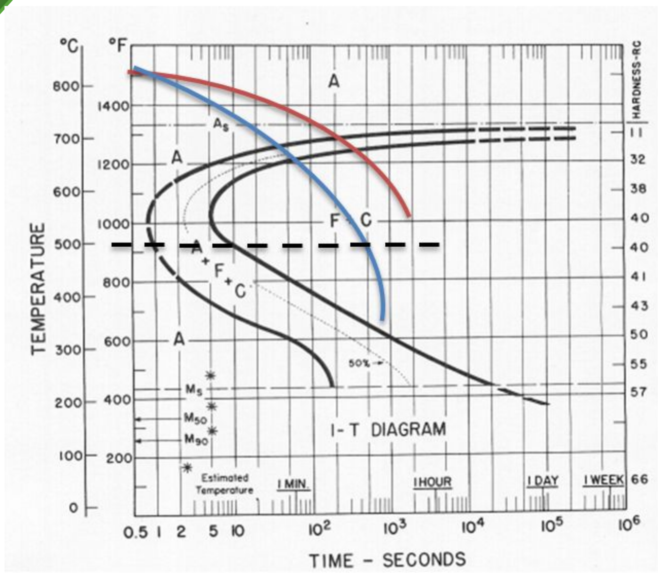
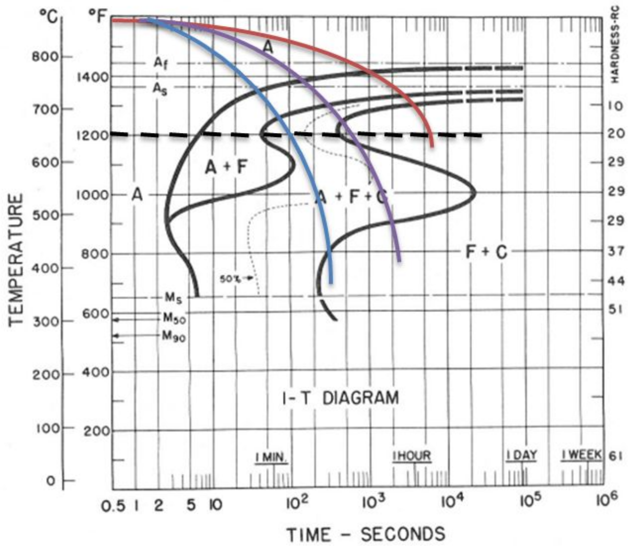


Region 3



TTT diagram of 1080 with 0.35% C and 0.37% Mn



TTT diagram of 4140 with 0.37% C, 0.77% Mn, 0.98% Cr and 0.21 Mo

The TTT diagram of low carbon MS shows transformation lines for cooling scenarios. The red line indicates retarded cooling, forming coarse pearlite with lower UTS and less brittleness, suitable for welding wires. The blue line represents forced cooling, producing fine pearlite with higher UTS but more brittleness. A dotted line through the transformation curve's nose separates fine and coarse pearlite regions.

The TTT diagram of an alloy grade from ECS shows cooling scenarios. The red line (retarded cooling) forms coarse pearlite with the lowest UTS and brittleness. The purple line (passing through the nose of the first C curve) forms fine pearlite with intermediate UTS and brittleness. The blue line (rapid cooling) forms bainite with higher UTS and increased brittleness. Fine pearlite formation is generally preferred for this alloy grade.

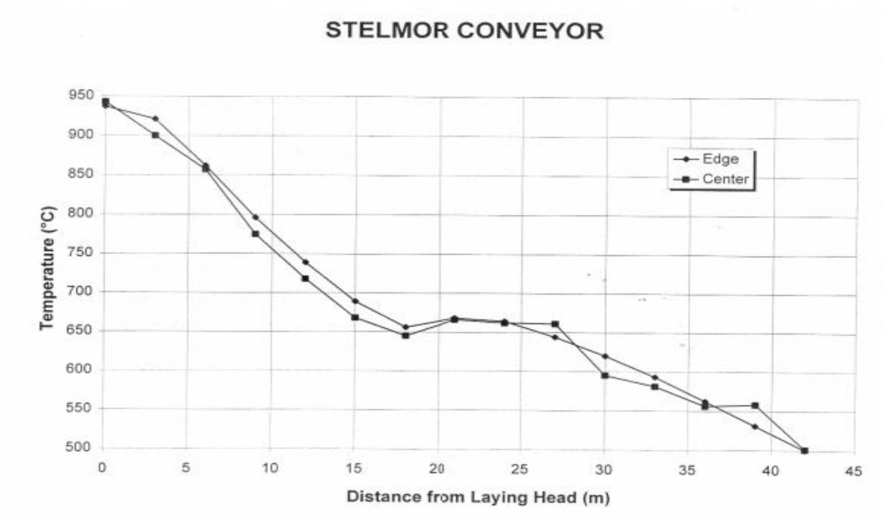


Figure 1.6 Temperature Profile for Grade 1055, 5.5 mm steel

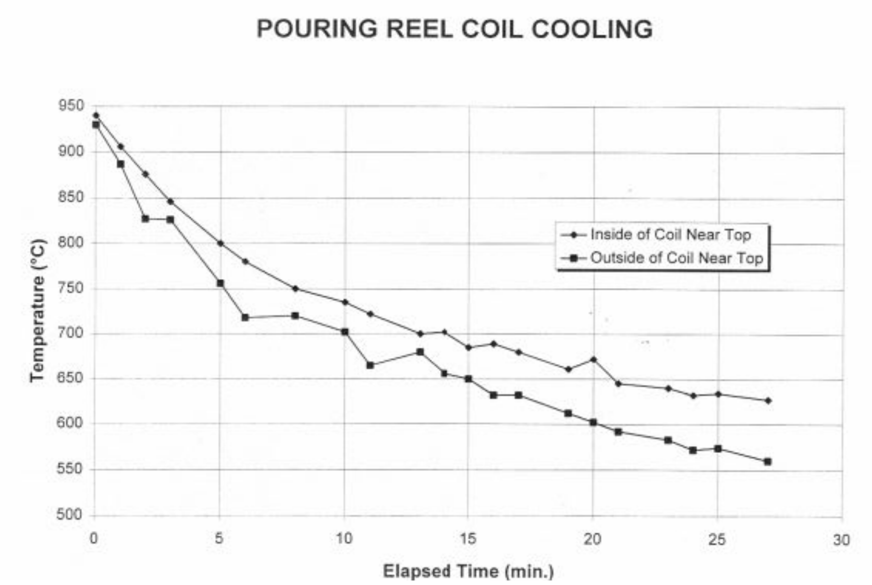


Figure 1.5 Temperature Profile for 1515 kg Coil, 15.5mm Bar

So with all this we can make a strong conclusion that the cooling rate very much affects the microstructure of the coil which in turn affects the mechanical properties like UTS, ductility and hardness.

But it's a concern that the temperature and hence the cooling rate is not monitored throughout the Stelmor Conveyor and if any anomaly is present it only gets revealed once the lab test is done.

Installation of pyrometer at each zones of Stelmor

The wire rod coils pass over the cooling nozzles on the Stelmor conveyor and are not in a static state, but always move forward with the rotation of the cooling conveyor equipment. Accordingly, a surface temperature profile of the wire rods measured with a contact thermocouple is not suitable for Stelmor air-cooling process. Kawasaki Steel Corporation has been using the wire rod coils attached to a pre-welded thermocouple to assess the Stelmor conveyor cooling performance, but this measurement method can only be applied to offline experimental equipment, and cannot be applied to the temperature measurements of an actual online Stelmor air-cooling production process.

Recently, the more commonly used instruments for wire rods temperature measurement on the Stelmor conveyor is the infrared pyrometer. In order to capture the surface temperature profile of wire rods during the Stelmor air-cooling process, the present investigation utilized both a single color and a dual-color pyrometer to test which type is better for wire rods temperature measurement. The size of the area (spot size) to be measured determines the distance between the pyrometer sensor and the wire rods. The spot size must not be larger than the wire rods coil.

There are three major positions (P1, P2 and P3) for taking temperature measurements. Both side positions (P1, P3) and the center position (P2) for the temperature measurement of the coils are 15cm and 60cm from the conveyor wall, respectively.

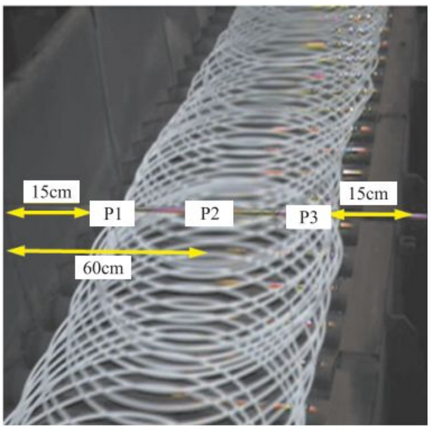


Fig.3. The positions (P1, P2 and P3) taken for temperature measurement.

Figure 4 shows the temperature measurement results using the dual-color pyrometer. The center position for the temperature measurement of the coils had more gaps between the wire rods, so the diagnostic signal from wire rod coils was unstable and fluctuant. However, at both the side positions for temperature measurement the coils were more compact and the diagnostic signal was more stable and repeatable.

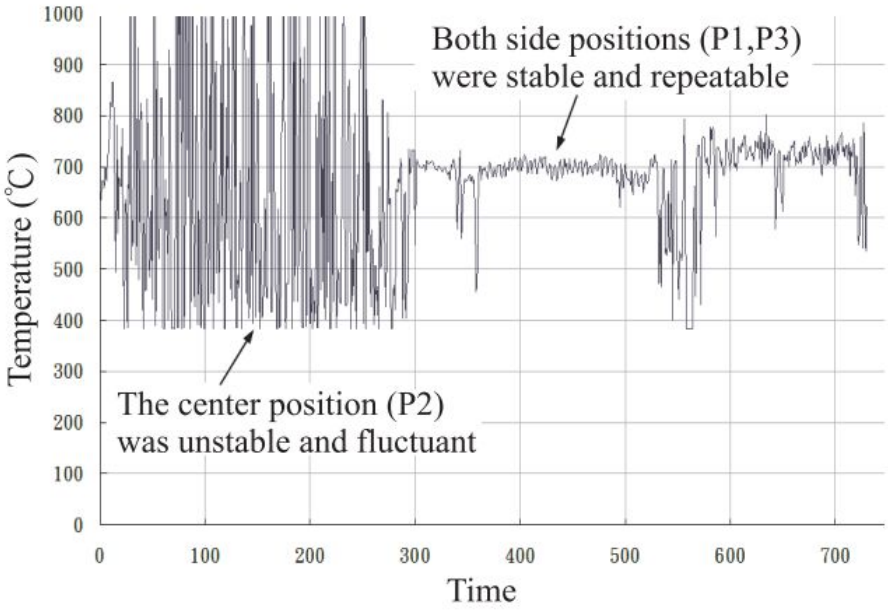


Fig.4. Both side positions were stable and repeatable.

Figure 5 shows the temperature measurement results of a single color pyrometer, clearly demonstrating that the temperature data for the center position (P2) of the coils was more stable than the data measured from dual-color pyrometer. **Therefore, single color pyrometer should be setup and installed for the wire rods temperature diagnosis in the Stelmor.**

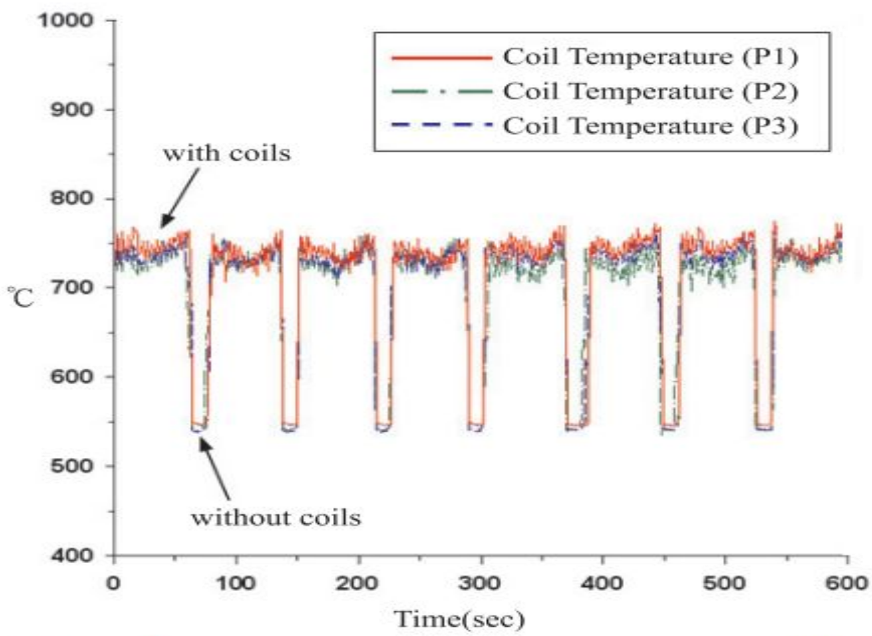


Fig.5. The temperature measurement results of the single color pyrometer.

Besides, there are also other mechanical equipments and electrical systems that need to be developed and designed for the novel online and movable temperature diagnostic system in the Stelmor air-cooling process. There are eight major components of the temperature diagnostic system designed for wire rods temperature measurement in Stelmor: (1) Single Color Pyrometer; (2) Movable Mechanical Platform; (3) 3-Axis Steering Gear; (4) The Encode; (5) Data Logger; (6) Water Cooling System; (7) Air Cooling System; and (8) The Extended Line.

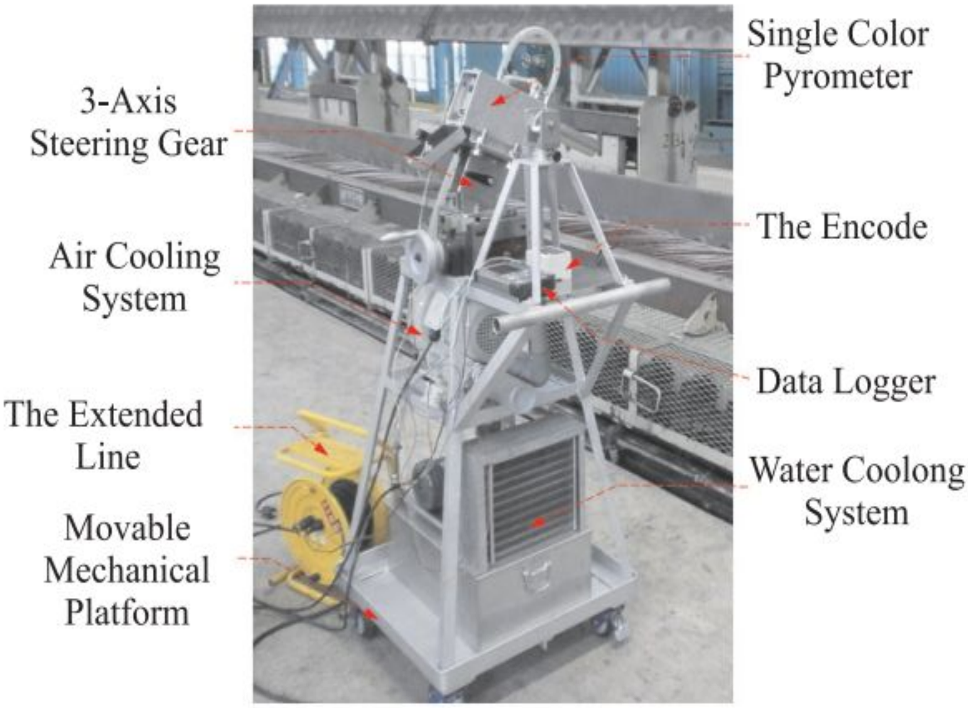


Fig.6. The novel online and movable temperature diagnostic system for Stelmor.

The temperature diagnostic system can be used for wire rods temperature measurement in different manufacturing processes including fast and slow air-cooling processes even for the case of within the encopanels on the Stelmor conveyor.

Fig.7(a). The wire rod temperature measurement for a fast air-cooling process (W/O Encopanels).

Fig.7(b). The wire rod temperature measurement for a slow air-cooling process (W/ Encopanels).

Figure 8 presents the surface temperature distributions in cross-section of NLP coils at different locations (Zone No.#1, Zone No.#2, Zone No.#6 and Zone No.#10) along stock. The wire rod surface temperature distributions measured in terms of the self- developed novel online and movable temperature diagnostic system reveals that the surface temperature distributions in the cross-section of NLP coils are not uniform

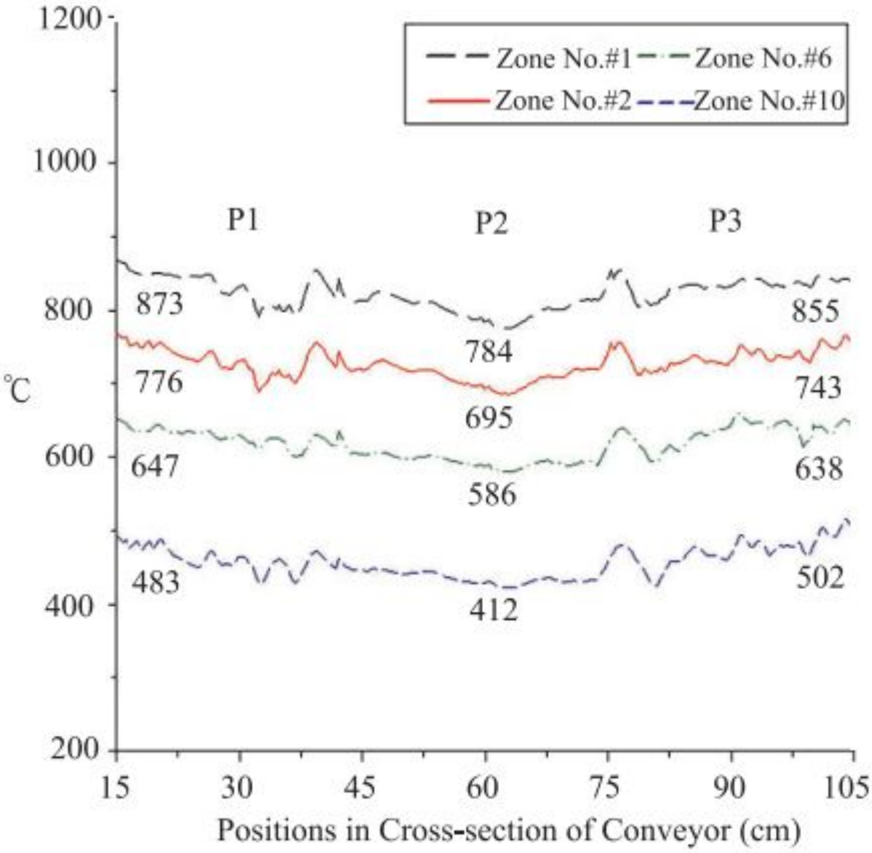


Fig.8. Surface temperature distributions in a cross-section of the conveyor at different zones.

Moreover, according to the continuous cooling transformation (CCT) diagram of NLP wires, the optimum phase transformation temperature is between 500 ~ 550℃. Because, a reheating effect occurs when the wire rods enter the slow cooling zone (Zone No.#6), the surface temperature of NLP wires rose to about 630℃. **Therefore, in order to capture the surface temperature of NLP wires, a novel online and movable temperature diagnostic system was designed for Stelmor air-cooling process in this study. Then, the temperature decay, i.e. the air cooling rate from Zone No.#1 to Zone No.#5, can be calculated, and the air cooling rate could be controlled**. **The cooling rate would help to predict the microstructures well in advance and we could then dynamically decide the process parameters during the run time itself. This will indirectly lead to more production and quality production, which will eventually lead to increase in OEE.**

Repairing the refractory material on the inner surface of the Stelmor cover

After doing a case study on MS grade, a few strong points got revealed. First a thorough analysis was done on the Quality report data. The data was cleaned and preprocessed using Python and Pandas to make a simplified sheet containing data with columns as sections, grades, Laying head temperature, Mill Speed and Conveyor Speed.

DATE- 01.01.2024				Dimensions (in mm)				Surface inspection						PROCESS PARAMETER			
M/C NO.	Heat No	Grade	Coil no.	Top/Bottom	Side	Shoulder	Ovality	Visual	Macro	Y S (N/mm^2)	UTS (N/mm^2)	RA%	EL%				
								SHIFT "ER"									
Ravi & Mithun								SAE1010			441MAX	60MIN	30MIN	LHT	M/S	C/S	BLOWER
MC-01	GD1924	SAE1010	C03B	10.04	9.98	10.18/10.15	0.2	OK	OK	254	366	60	31	900	68	12	ALL OFF
MC-01	GD1927		C02B	10.06	9.96	10.17/10.16	0.21	OK	OK	262	370	61	32				
MC-01	GD1929		C01B	10.07	9.98	10.18/10.17	0.2	OK	OK	252	364	66	32				
								SAE4140			980MAX	40MIN		LHT	M/S	C/S	BLOWER
MC-01	4322906		C01B	10.05	9.99	10.17/10.15	0.18	OK	OK	538	872	44		900	68	12	ALL OFF
MC-01	4322908		C01B	10.04	9.98	10.17/10.16	0.19	OK	OK	529	863	45					
MC-01	4322911		C01B	10.06	10	10.16/10.15	0.16	OK	OK	550	891	41					
								SAE1018			491max	65min	30min	LHT	M/S	C/S	BLOWER
MC-01	GD1406		C01B	10.05	10	10.16/10.12	0.16	OK	OK	301	466	65	31	900	68	12	ALL OFF
MC-01	GD1399		C02B	10.06	9.98	10.18/10.14	0.2	OK	OK	305	470	63	30				
MC-01	GD1404		C02B	10.06	9.98	10.16/10.14	0.18	OK	OK	296	461	66	32				
								HC81/85(P)						LHT	M/S	C/S	BLOWER
MC-01	4322078		C01B	10.02	9.94	10.12/10.10	0.18	OK	OK		1164	26					
MC-01											1155	28					
MC-01			C02B	10.03	9.95	10.14/10.08	0.19	OK	OK		1162	31					
MC-01											1136	28					
								SHIFT "DB"									

01.01.2024 | 02.01.2024 | 03.01.2024 | 04.01.2024 | 05.01.2024 | 06.01.2024 | 07.01.2024 | 08.01.2024 | 09.01.2024 | 10.01.2024

	A	B	C	D	E
1	Section	Grade	LHT	M/S	C/S
2	5.5	HC76BX	875	100	55
3	5.5	SAE1010	900	100	12
4	5.5	HC42AX	920	100	55
5	5.5	SWRH82A	920	85	55
6	5.5	HC76AX	900	100	55
7	5.5	HC76BX	910	100	55
8	5.5	SWRH62A	920	100	55
9	5.5	HC 51/55	915	95	55
10	5.5	EM12K	890	104.64	14
11	5.5	HC76AX	920	100	55
12	5.5	HC76AX	900	100	55
13	5.5	HC76BX	908	100	55
14	5.5	SAE1010	900	100	12
15	5.5	EQ	900	100	16
16	5.5	SAE10B21(M)	900	100	10
17	5.5	HC56AX	920	100	55
18	5.5	SAE1008	900	100	18
19	5.5	SAE1022	912	100	20
20	5.5	HC42AX	910	100	55
21	5.5	SAE1008	890	100	16

Sheet1 | Pivot Table 1

FIG: Data cleaning and preprocessing

Now analyzing on this preprocessed data, the conclusion that could be made was for MS the conveyor speed was kept in the range of 10-20 m/min and for majority it was below 15 m/min. For mild steel we need retarded cooling i.e the blowers aren't operating so the conveyor has to be run at a slower speed with the hoods being closed. The slower speed ensures that no forced convection happens and closed hood ensures that the heat is kept trapped to delay the cooling. But if we refer ECS, for retarded cooling the conveyor can run even at a speed of 25-30 m/min.

JSP Limited

7.1 STANDARD STELMOR CONVEYOR SPEEDS

SIZE (mm)	MILL SPEED (m/sec)	STANDARD STELMOR CONVEYOR SPEEDS (M/MIN) ENTRY	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6	ZONE 7	ZONE 8	ZONE 9	ZONE 10	ZONE 11	REFORM
5.5	110	72	79	87	91	96	101	106	106	106	106	90	77	61
8	107	80	88	97	102	107	112	118	118	118	118	100	85	68
10	68	79	87	96	100	105	111	116	116	116	116	99	84	67
12	47	64	70	77	81	85	90	94	94	94	94	80	68	54
16	26	48	53	58	61	64	67	71	71	71	71	60	51	41
20	17	39	43	47	50	52	55	57	57	57	57	57	57	46

7.2 RETARDED STELMOR CONVEYOR SPEEDS

SIZE (mm)	MILL SPEED (m/sec)	RETARDED STELMOR CONVEYOR SPEEDS (M/MIN) ENTRY	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6	ZONE 7	ZONE 8	ZONE 9	ZONE 10	ZONE 11	REFORM
5.5	110	11.0	11.0	11.6	12.1	12.7	13.4	13.4	13.4	13.4	13.4	17.4	22.6	29.4
6.0	110	14.6	14.6	15.3	16.1	16.9	17.7	17.7	17.7	17.7	17.7	23.1	30.0	39.0
6.5	110	18.4	18.4	19.3	20.3	21.3	22.4	22.4	22.4	22.4	22.4	29.1	37.8	49.1
8	107	29.0	29.0	30.5	32.0	33.6	35.2	35.2	35.2	35.2	35.2	45.8	59.6	77.4
12	47	25.0	25.0	26.3	27.6	28.9	30.4	30.4	30.4	30.4	30.4	39.5	51.4	66.8
16	26	21.0	21.0	22.1	23.2	24.3	25.5	25.5	25.5	25.5	25.5	33.2	43.1	56.1
20	17	18.6	18.6	19.5	20.5	21.5	22.6	22.6	22.6	22.6	22.6	29.4	38.2	49.7

The important thing to note here is for MS with increase in conveyor speed the cooling rate increases. The reason being with increase in conveyor speed forced convection happens. But we are getting the desired microstructure at a conveyor speed of around 10-15 m/min. Now if we increase this conveyor then the cooling rate is going to increase and we will be getting finer pearlite but for the majority of use cases of MS we need formation of coarse pearlite. So from the fact that conveyor speed of 25-30 m/min is mentioned in ECS, we can conclude the problem that the cooling rate is remaining higher than it should have been in the ideal case.

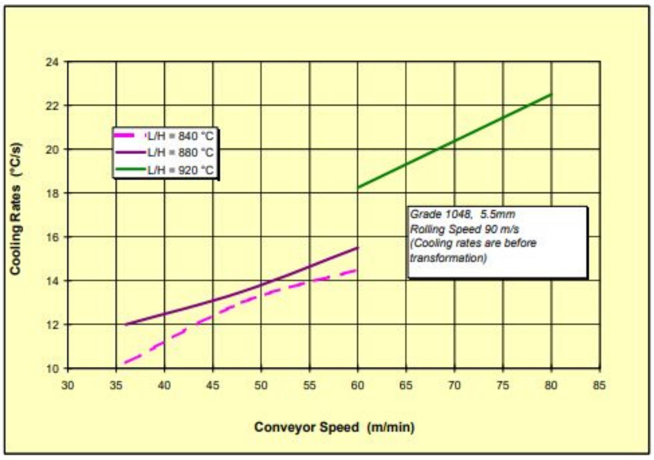


Figure 6.1 The effect of laying temperature and conveyor speed on cooling rate.

The Stelmor conveyor hood comprises of three layers. The inner one is of refractory material which has the least heat transfer coefficient. It is the most prominent layer for heat insulation. It has heat transfer coefficient in the range coefficient in the range of 1-5 W/m²·K. The middle layer is of wood and it has a heat transfer coefficient of 5 – 30 W/m²·K. The outer layer is of stainless steel whose main functionality is to provide the necessary structural support. It has heat transfer coefficient in the range of 200 – 600 W/m²·K.

Material	Heat Transfer Coefficient (W/m²·K)
Refractory Materials	1 - 5
Wood	5 - 30
Stainless Steel	200 - 600

Now doing minute observations along this line some root causes popped up. The prominent one being the refractory material on the inner surface of the stelmor conveyor has been deteriorated.

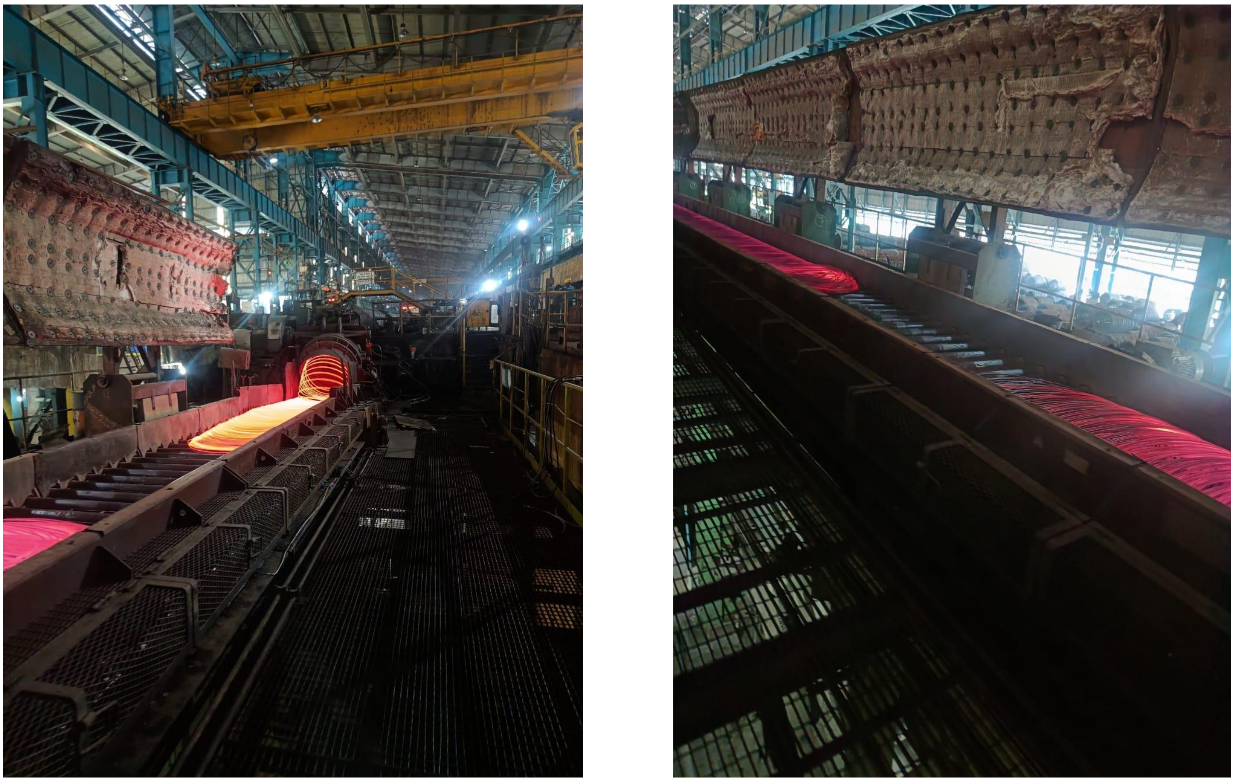


FIG: Deteriorated inner surface of the Stelmor Cover

So a proper audit of the Stelmor hood needs to be done. A well maintained Stelmor hood will help to run the MS grade at a faster speed on the Stelmor conveyor. Faster speed of the Stelmor will lead to the reduction in the inter billet gap, which is currently at around 10-15 sec and ideally according to PrimeMetals, it should be of 5 sec. In the whole supply line of processing of the billet to wire rod, **Laying head is the point where the inter billet gap is the lowest.** This conclusion was made by doing primary research by checking the billet gap at 7 checkpoints. The 7 checkpoints were Furnance, Stand 10, Stand 14, Water Zone 1, Water zone 2, NTM, Laying Head and Reform Tub. **But finally it is that faster the speed of the Steylmore conveyor, more will be the production. More production will lead to the increase in the performance factor of OEE which will eventually lead to the increase of OEE.**

Maintenance of the perforations on the conveyor bed

There are air perforations on the conveyor bed which help in uniform cooling as well as proper directional flow of the air to the coils. For the case of high carbon grade, all the blowers are running and they run at their full capacities. There are 12 blowers at JSP Patratu. Also in this case the Stelmor covers are kept open. In case of HC, forced cooling takes place. Currently the Stelmor conveyor runs at a speed of 55 m/min.

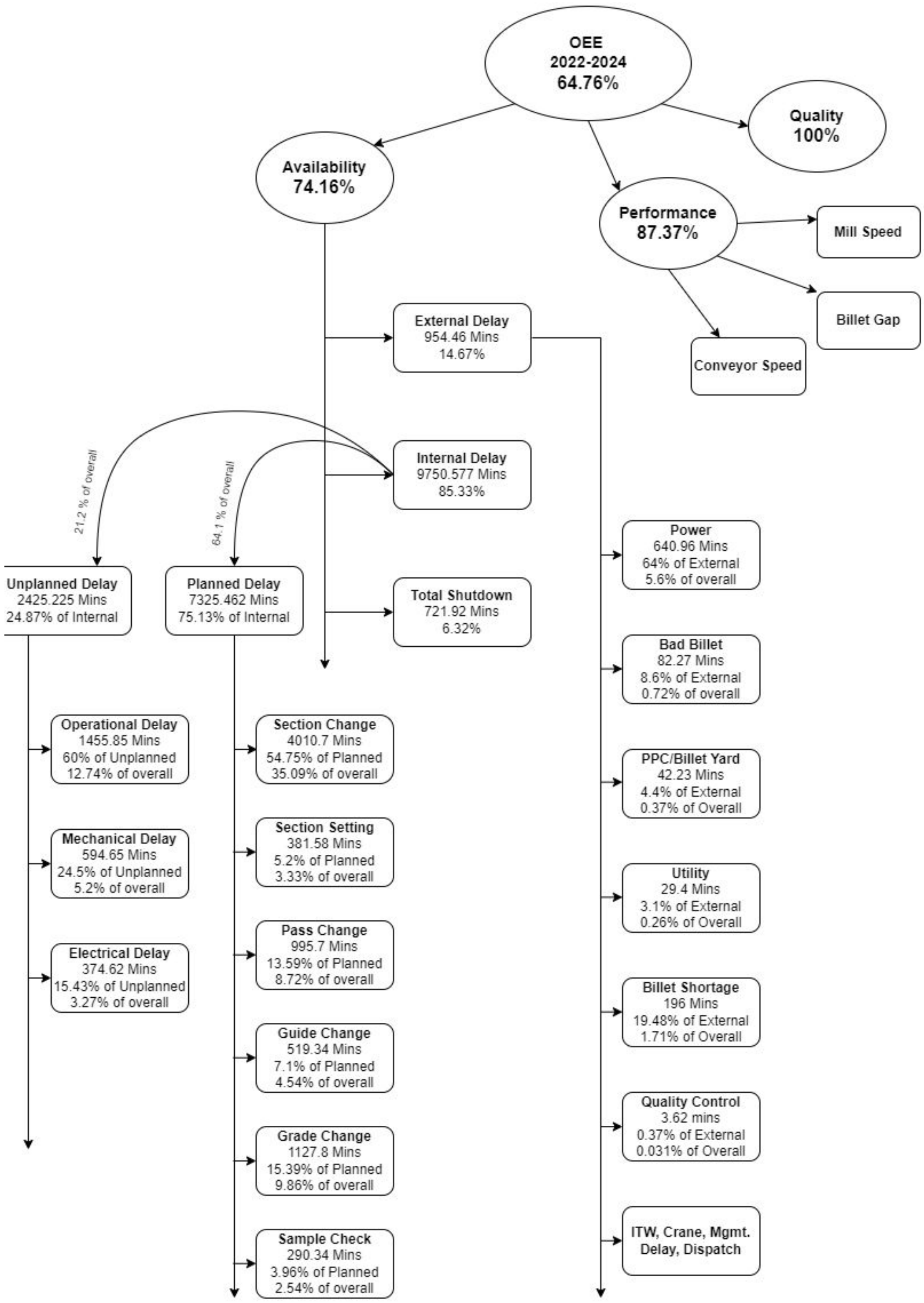
For HC we need forced cooling because we need higher UTS as compared to the case of MS. The forced cooling leads to the formation of fine pearlite which has higher UTS than coarse pearlite. So higher cooling rate is desirable and proper perforations help in uniform and faster cooling. We could observe in the pictures below taken from the Stelmor Conveyor at WRM JSP Patratu. In many cases the gap between the perforations have been sealed. The are exposed to high temperature and high stress which has caused the thermal expansion that has led to the undesired change in the shape. It blocks the flow of the air to the wires moving over it which causes non uniform and slower cooling. To cater to this the blowers needs to be run at a higher speed and the conveyor needs to be run at a slower speed so that this loss of cooling due to blockage of air flow could be compensated.

FIG: Deteriorated air perforations over the Stelmor bed

2. Online quality checking to reduce unplanned delay

Observations

The ongoing quality check in the mill takes place only once the wire is completely rolled, that it is not real time. And also the quality checking is done mainly at two spots that are near the laying head and the reform tub. There are no numerous checkpoints for quality checking which would help in rapid debugging and quickly finding the root cause of quality issues. Also the testing is done only on the head and tail part of the coil so sometimes it may not give the true picture.

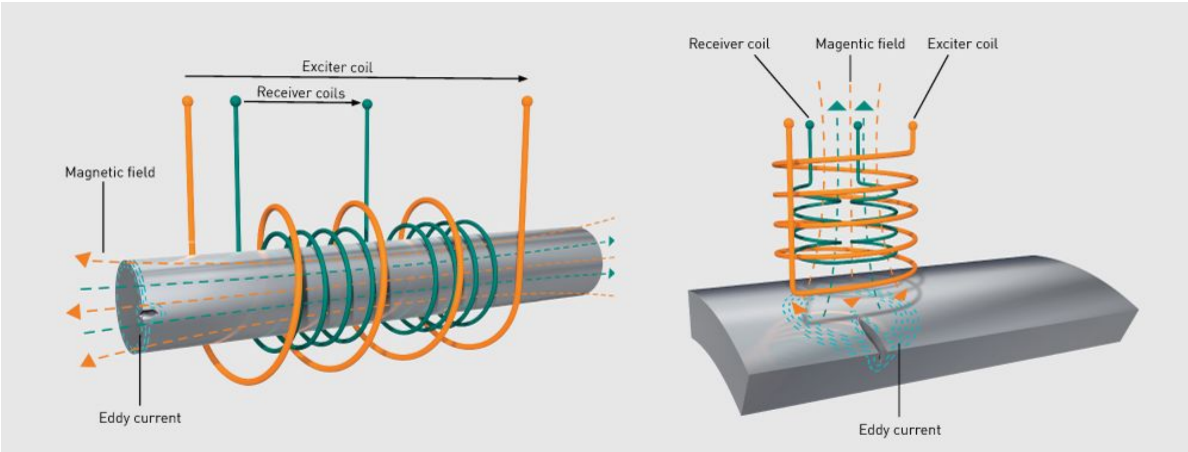


Solution

To improve quality and efficiency, wire rods can be tested while it's hot during production (hot testing) instead of waiting until later stages. This allows for early detection and correction of issues, reducing scrap and improving overall production.

Technology

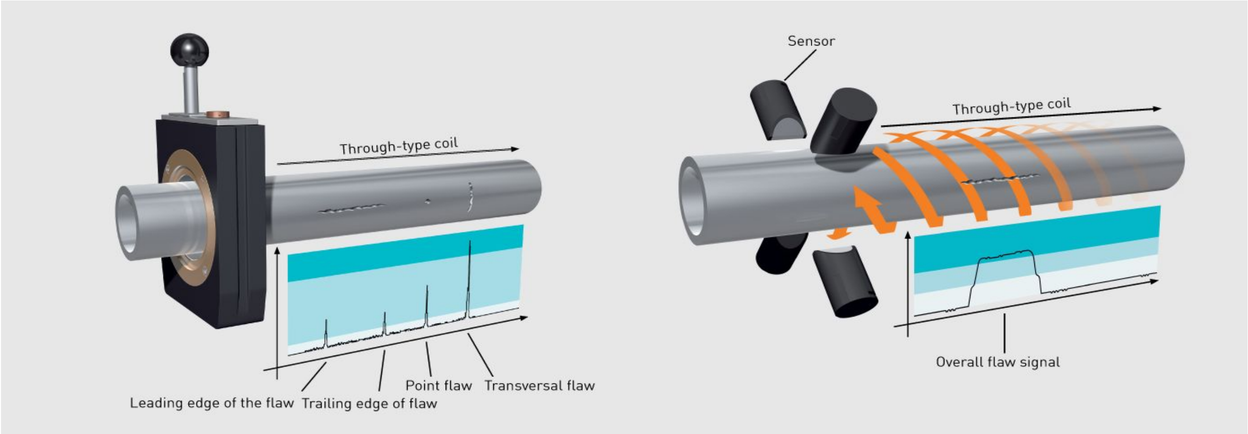
Eddy current testing is a non-destructive method for detecting surface defects in metals. It uses high-frequency electromagnetic interactions to identify cracks or discontinuities without damaging or contaminating surfaces. Capable of detecting defects as small as 30 µm, this contactless method is ideal for both manual and automated evaluations.



Modern sensors, electronics, and software provide diverse applications for the metal industry and mobile maintenance testing. Its low media consumption and maintenance costs make eddy current testing economical and environmentally friendly. Additionally, its high testing speeds and automation ensure uninterrupted production processes, making it popular for 100% testing in production.

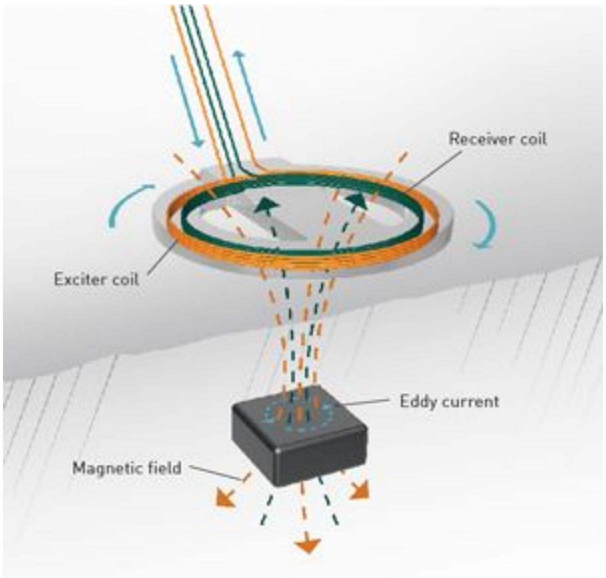
Eddy current testing for semi-finished products and components uses frequencies up to 10 MHz to detect surface defects in metals. Differential measurement coils, both standard and customized, are commonly used.

Encircling coils inspect wires, rods, and tubes for transverse cracks and holes, while rotating probes test for longitudinal defects on surfaces. Stationary probes can assess critical points on components. Sensor selection depends on the specific testing task, enabling high defect resolution.



In metal detection, eddy current testing is used to generate an electromagnetic field with one or two frequencies that can be used to detect even the smallest quantities of hidden metals (e.g., steel, Fe, Al, Cu, Au, Ag).

The detection sensor emits an electromagnetic field to detect metallic objects using active sensors. This produces eddy currents in the detection object that in turn generate a secondary electromagnetic field that is detected by the detection sensor and used for evaluation.



Technology

Test Head

The 'Defectotherm' instrument used for the investigation utilizes well-known eddy current test principles with feed-through coils in a differential arrangement. The interchangeable measuring coils are water-cooled, and are housed in a small coil holder (Fig 2). The test frequency must be high to ensure good defect resolution at high test speeds. Fortunately, high frequencies are allowed by eddy current theory because of the low conductivity of hot material.

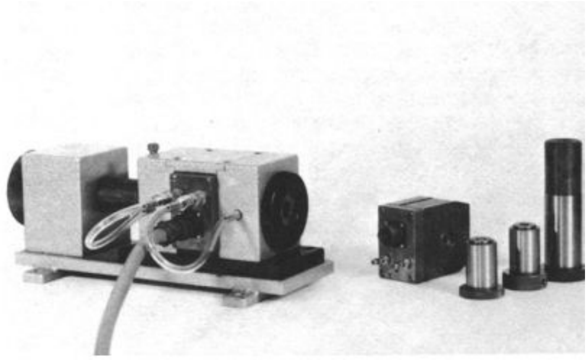


Fig 2 Interchangeable measuring coils and coil holder

For example, hot steel wire of 10 mm diameter can be tested at 1100°C at 90 kc which results in test frequencies are allowed by eddy current theory because of the low conductivity of hot material.

For example, hot steel wire of 10 mm diameter can be tested at 1100°C at 90 kc which results in test speeds of up to 50 m/sec. In general the demands for testing welded steel tubes, or tubes and wire in Aluminium and Copper are less severe. Optical sensors at the in- and output of the coil holder start and stop the electronic devices. Fig 3 shows the test head in a production line.

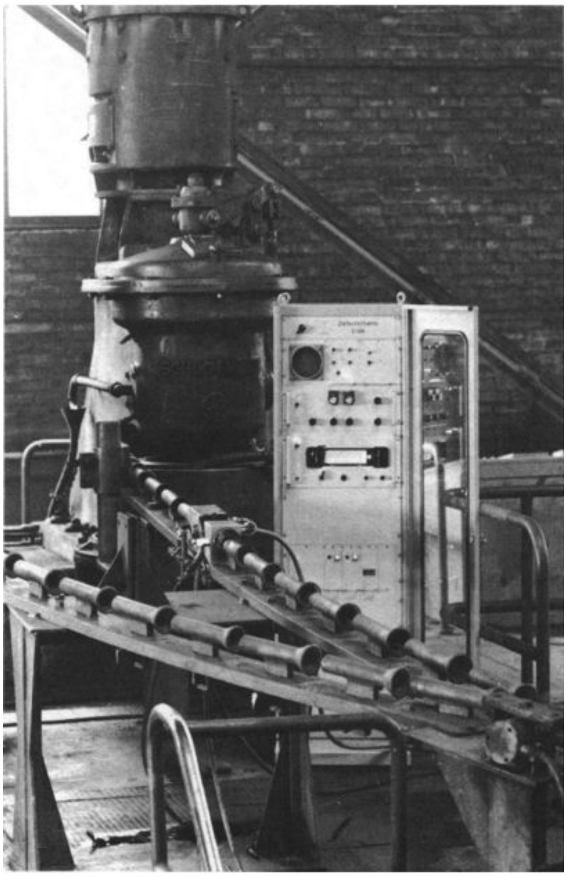


Fig 3 Test head in a production line

Electronics

The high-frequency eddy current signal from a defect contains the defect indication both m amplitude and phase. Signal processing is affected by a triggered rectifier which reproduces the vector of defect voltage. The point of this vector is visualized on a C.R.T. screen.

A high-pass filter suppresses undesired frequency components in the signal caused by slowly varying parameters such as temperature and dimension.

The signal is then processed by two amplitude discriminators, which classify the signals into three groups: Signal amplitude below the first threshold; between the first and a second higher threshold; and above the second threshold (i.e negligible defects, small defects, and large defects). The discriminator signals are also fed into a digital evaluation unit which prints out the number of large defects, and the total of large and small defects within the wire sections.

The relationships between defect depth and eddy current indications are statistical because of the different shapes and types of natural defects in rolled wire and the differential arrangement of the measuring coil. The statistical relation between the percentage of defects which can be detected by the test method under given conditions (probability of detection), and defect depth will enable a user to estimate the possibilities of the test method.

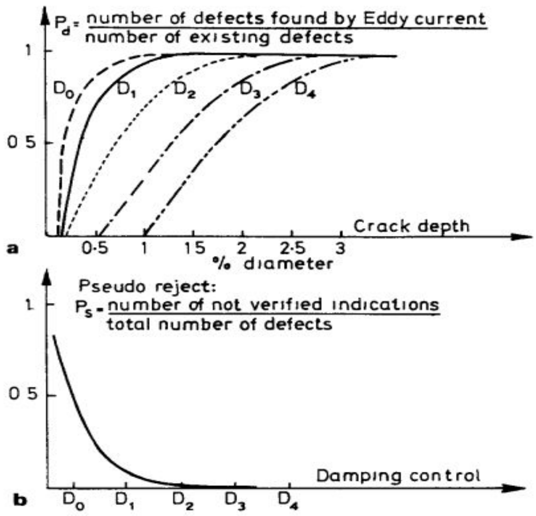


Fig 4 Hot wire rod testing. (a) Showing the ratio of the number of defects found by eddy current testing to the number of existing defects, as a function of the defect diameter. (b) Showing the pseudo defect as a function of damping

Fig 4a shows, as a function of defect depth, (percentage of wire diameter) the ratio of the number of defects found by eddy currents to the number of existing defects (found, for example, by microscopic control at points where eddy current test shows defects) of ferrous wire (18 mm in diameter). The damping control (reciprocal of sensitivity) of the amplifier in the test unit is the parameter. Fig 4b clearly shows the situation. At the relatively low damping D1 (high sensitivity) of the instrument defects of 0.15 mm depth (approximately 0.8% of the diameter) and more are detected with a probability of nearly 100%. Smaller defects can still be found, but with a lower probability of, for example, 75% at 0.1 mm crack depth (0.6%). Even defects with a depth of 50 ~m (0.3°1o of the diameter) are within the detectability, but the probability of detection tends to zero at the limit of the test method at 20 ~m. A higher damping D2 (reduced sensitivity) shifts the function toward larger crack depths. An increased sensitivity (eg at Do) cannot improve the lower limit.

Future Scope

In more advanced setups, Defectomat systems can be part of an integrated quality control system that combines data from multiple sensors and monitoring devices. This integrated system can then use algorithms and machine learning to suggest or even automatically apply adjustments to the mill's operational parameters to minimize defects and maintain consistent product quality.

3. Induction heating of the billet head to reduce scrap at shear and increase yield

There are three points in the production line at WRM JSP Patratu where head/ tail cutting takes place. They are shear 1, shear 2 and shear 3. Shear 1 is just after stand 5&6 and before the intermediate stands. Here only the head part of the billet is chopped. After this Shear 2 is between Stand 12 and Up Looper 2. Here both the head and the tail of the billet is chopped off. Finally Shear 3 is after NTM pinch roll and before the Side Looper 3.

The main purpose for chopping off of the head/tail is the cooling of the extremes as the billet pass along the production line. If not chopped issues will biting issues will arise near the subsequent stands and there will be increase risk of cobble.

But the issue is that it leads to significant loss in yield, which subsequently impacts the performance factor of OEE as it is the actual production by rated production. Loss in yield is a loss in actual production. So to cater to this inductive heating coils can be installed to timely heat the head and tail of the billet so that the length of the chopped off part can be significantly reduced.

SHEAR 1				
Sections	Length chopped(in cr	Area after stand 6(in mm2	Volume(in m3)	In kgs/billet
5.5	40	4652	0.0018608	14.60728
6	35	4652	0.0016282	12.78137
6.5	30	4652	0.0013956	10.95546
7.5	26	4652	0.00120952	9.494732
8	28	4652	0.00130256	10.225096
8.5	30	4652	0.0013956	10.95546
9	22	4652	0.00102344	8.034004
9.5	20	4652	0.0009304	7.30364
10	22	4652	0.00102344	8.034004
11	30	4652	0.0013956	10.95546
12	30	4652	0.0013956	10.95546
13.5	26	4652	0.00120952	9.494732
14	20	4652	0.0009304	7.30364
15	15	4652	0.0006978	5.47773
16.3	15	4652	0.0006978	5.47773
18.5	25	4652	0.001163	9.12955
20	16	4652	0.00074432	5.842912
22.3	16	4652	0.00074432	5.842912
23	13	4652	0.00060476	4.747366
24	15	4652	0.0006978	5.47773

SHEAR 2						
Sections	Head chopped(	Tail Chopped(in cm)	Head + Tail	Area after Stand 12(in mm2)	Volume(in m3)	In Kgs/Billet
5.5	24	22	46	857	0.00039422	3.094627
6	27	26	53	857	0.00045421	3.5655485
6.5	30	32	62	857	0.00053134	4.171019
7.5	35	35	70	857	0.0005999	4.709215
8	36	34	70	857	0.0005999	4.709215
8.5	38	40	78	857	0.00066846	5.247411
9	40	40	80	857	0.0006856	5.38196
9.5	50	40	90	857	0.0007713	6.054705
10	35	35	70	857	0.0005999	4.709215
11	35	50	85	857	0.00072845	5.7183325
12	35	32	67	857	0.00057419	4.5073915
13.5	48	36	84	857	0.00071988	5.651058
14	35	40	75	857	0.00064275	5.0455875
15	35	35	70	857	0.0005999	4.709215
16.3	48	35	83	857	0.00071131	5.5837835
18.5	52	32	84	857	0.00071988	5.651058
20	55	30	85	857	0.00072845	5.7183325
22.3	50	33	83	857	0.00071131	5.5837835
23	53	40	93	857	0.00079701	6.2565285
24	51	36	87	857	0.00074559	5.8528815

By the above analysis and calculations we can see that there is on an average a loss of around 10 kgs near shear 1 and a loss of around 5 kgs near shear 2. **So there is a total loss of around 15 kgs due to shear chopping**. The loss at shear 3 is 20th part of the loss at shear 1 which is quite insignificant. For the above analysis the contract book was referred to get the cross reduction at different rolls for different sections. The density of billet was assumed to be 7850 kg/m3. So by introducing inductive heating coils in the 42m rolling table we can reduce this scrap significantly. The 42m rolling table is chosen because almost all the shear loss happens at shear 1 and 2 itself and the ends of billet mostly gets cooled in the 42 m rolling table region only.

Let's assume that we got to **save 50% of the scrap metal** due to shear cutting by implementing this inductive heating coil. So it save **7.5 kgs of steel per billet**. Now taking **1st April as a dummy to check the impact** of this solution. The rated production and actual production for 1st April 2024 were 1437.45 Tons and 1233.175 Tons respectively. The **performance factor was 85.79%**. If this equipment would have been in place then the actual production would have been 1237.48735 Tons that is **4.31235 Tons more**. The **performance factor would have been 86.08%**. So we could see a **0.29% rise in the performance factor** by only implementing this solution. This solution has other benefits too that will add to OEE. Online heating of the head would reduce the number of cobbles, which in turn will reduce the unplanned delay and will again contribute to increase of OEE.

Findings

My findings to increase OEE can be classified into three categories i.e The Stelymore Region, Online quality checking to reduce unplanned delay and inductive heating of the head of the billet to reduce scrap loss at shear

Opportunities near the Stelmor Region

Online prediction of the cooling rate of the wires on the Stelmor Conveyor	The properties of hardness, ultimate tensile strength (UTS), and ductility are influenced by the cooling rate at the Stelmor Conveyor. However, there is no device in the Stelmor region at WRM JSP Patratu to predict microstructure transformation. Currently for desired and accurate properties, running parameters are modified only after proper lab tests are done and it takes time.
Increment in the current speed of stelmor conveyor to match the rated for MS Grade	The current operating speed for Stelmor Conveyor for MS grade is in the range of 10-15 M/min but according to ECS it can be in the range of 20-30 M/min. MS grade demands retarded cooling for formation of coarse pearlite and in this case the cooling rate increases with the increase of conveyor speed. But slower speed than rated indicates higher cooling rate. So the necessary heat couldn’t be trapped.
Repairing of the air perforations over the conveyor bed	For HC, forced cooling is necessary to achieve higher UTS, as it forms fine pearlite with higher UTS than coarse pearlite. A higher cooling rate and proper perforations ensure uniform and faster cooling. However, pictures from the Stelmor Conveyor at WRM JSP Patratu show that many perforations are sealed due to thermal expansion from high temperature and stress, blocking airflow and causing non-uniform, slower cooling. To compensate, blowers must run at higher speeds, and the conveyor must run slower to maintain effective cooling.

Online quality checking to reduce unplanned delay

Eddy current technology to detect scratch lines online

Operating delays account for 12.74% of the total delay, which is a part of the unplanned delay. The primary cause of this operating delay is the development of scratch lines on the wire rods. Defectotherm online scratch line checking equipment uses Eddy current technology to statistically determine the concentration of scratch lines and their intensity on the surface of the wire rod. This can be equipped with machine learning algorithms to classify the quality issue and will help to rapidly find out the root cause, reducing operational delays.

Inductive heating of the head of the billet to reduce scrap loss at shear

Inductive heating coils to heat the billet heads

A significant material loss happens due to head cutting at Shear 1, 2 and Trim shear. A significant amount of this material loss can be saved if we implement some inductive heating equipment to heat the head of the billet so that with lesser cutting length of the billet head we won’t get biting issues at the rollers. These can be installed along the 42m rolling bed as Shear 1 and 2 present right after that. This will help to increase the yield which will ultimately result in increase of the performance factor of OEE and hence contributing to the increase of OEE.

Issues with data logging and need of MES

One of the stepping stones for Industry 4.0 is the MES

Traditional data logging methods are prone to errors, time-consuming, and lack real-time insights, leading to inconsistent quality and inefficient operations. Implementing a Manufacturing Execution System (MES) software streamlines data collection, enhances accuracy, and provides real-time monitoring and control. MES software improves traceability, ensures consistent product quality, optimizes production processes, and reduces downtime through predictive maintenance and data-driven decision-making, resulting in increased operational efficiency and productivity.

Conclusion / Recommendations

Tracking of cooling rate for properties predictions and setting parameters	Install single color pyrometer in each region of Stelmor to quickly find the reasons for non-uniformity. Control plan can be revised fast to convert non-prime to prime. It will help in fast decision making
Opportunities under MS Grade in the Stelmor Region	Repairing of the refractory layer over the Stelmor cover to retain the escaping heat and facilitating retarded cooling.
Opportunities under HC Grade in the Stelmor Region	Repairing of the air perforations over the Stelmor bed to ensure proper flow of air to facilitate uniform and forced cooling
Online quality checking to reduce unplanned delay	Installing a Defectotherm scratch line detecting machine just after RSM
Inductive heating of the head of the billet to reduce scrap loss at shear	Installing 2 Inductive heaters on the 42m rolling table to heat the head of the billet
Installment of MES software	Installing an MES software to monitor, track, document and control the entire production lifecycle