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IMPACT OF IMPLEMENTING RELIABILITY MANAGEMENT PRACTICES ON ORGANIZATION'S YIELD

Vibhuti Aditya Save
Assistant Professor, Dr. V. N. Bedekar Institute of Management Studies, Thane, India.

Abstract
This paper focuses on how Reliability Management Technique helps an organization to prioritize and to design their maintenance schedule. It shows that, on basis of continuous observations, effective conclusions can be drawn from the relevant values of reliability parameters (MTBF, MTTR).It presents the findings of the work carried out at JSW Steel Ltd. at Tarapur production plant during the period of May'10-June'10. A Project entitled "Study of unit wise equipment breakdown and application of reliability techniques, to improve the performance of Color Coating Line – II (CCL-II)" was undertaken during this tenure. In this span, all the breakdowns of degreasing unit and quench tank unit of CCL-II section were studied for the period of one year; also frequency analysis of different types of error was done for the maintenance activities of both the units.

The main objective of the initiative was to increase the reliability of a finished goods line, i.e. to increase MTBF (Mean Time Between Failure) and to reduce MTTR (Mean Time To Repair), so that loss of production in CCL-II section because of degreasing unit and quench tank unit can be reduced.

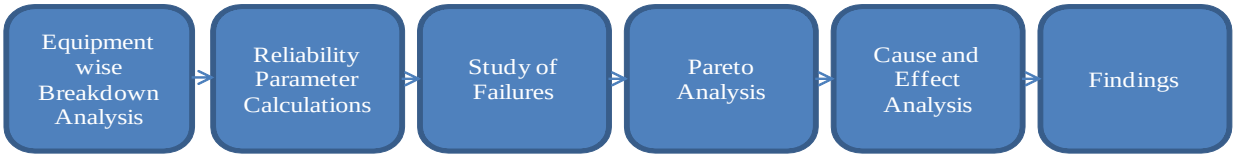
Keywords: Reliability Management Technique, MTBF (Mean Time between Failures), MTTR (Mean Time to Repair).

Approach

This research paper mainly aims at improving the efficiency of finished goods line (Color Coating Line) of JSW Steel Ltd. For this purpose, we have studied equipment wise breakdowns of Degreasing Unit and Quench Tank unit of Color Coating line.

Approach

- To begin the study, mechanical maintenance logs books for the period of 14 months (April-2009 to May-2010) are analyzed to note failures of sub parts in degreasing and quench tank unit.
- Total number of failures occurred during this tenure and total time loss, reliability parameters such as MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair) are calculated.
- After calculating reliability parameters, nature of failures has been studied. This has been done on basis of different types of errors observed, frequency of the errors and solutions given by the operators during that moment.
- Based on error frequency, Pareto Analysis has been done to distinguish most critical issues from performance of Color Coating Line's point of view.
- Based on error information, root cause of the failures has been analyzed with the help of Cause and Effect Analysis approach. This will help the management to highlight the issues and focus on critical issues.
- Finally on basis of Reliability Parameters, FMEA Analysis and Pareto Analysis, our findings have been submitted to Mechanical Maintenance team of JSW Steel Limited. These findings will help them to formulate maintenance schedule for their Finished Goods line.



Approach of Research

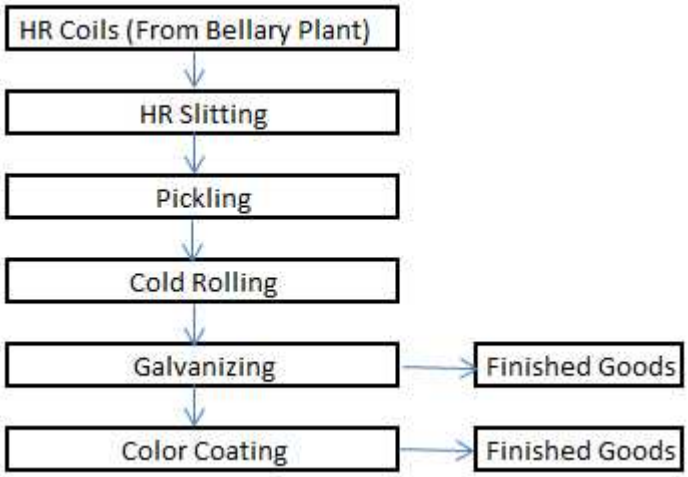
INTRODUCTION

The Tarapur plant offers coated products catering to several sectors. It specializes in galvanizing, Galvalume and color coated steels. The Tarapur plant has five cold rolling mills and five coated strip divisions, which include two dual pot galvanizing cum galvalume lines and two color coated lines.

Unique features

- The Tarapur plant is specialized for the Ultra Thin Coated Products.
- The Tarapur plant features two dual product lines for galvanized cum Galvalume with a coating capacity of 0.45 MTPA (Million Tons per Annum)
- It also has 30 MW Captive Power Plant (CPP) to meet the power requirement of both Tarapur and Vasind plant.
- Tarapur has a zero discharge facility having a multi-effect evaporator system for effluent treatment.
- It has a unique service center facility to meet the customized requirement of various segment like Export, OEM, Retail for their cut sheet/ corrugation and profiling requirement

Manufacturing process at JSW Steel Ltd



Manufacturing Process at JSW Steel Ltd. – Tarapur plant

- **HR Slitter**
  In this, the hot roll coils are cut from both sides or from a single side into sheets of desired width as per specifications. Slitter takes out the damaged edges if there are any.
- **Pickling**
  In this step, coils are rinsed with the solutions such as HCL acid to remove the rust on the HR coils.
- **Cold Rolling**
  In this step, thickness of sheets is reduced according to customer's requirement. At this manufacturing unit, there are 3 cold rolling mills (TM4, TM5 and TM6). These mills are reversible mills. While reducing the thickness of the sheets, uniform tension on the coil is maintained.
- **Galvanizing**
  In this step, cold rolled sheets are coated with zinc or aluminum, hence the name Galvanized Iron (GI) and Galvalume (GL) respectively. Galvanized sheets (GI and GL) are finished products of this plant. If customer wants painted steel sheets, then these galvanized sheets are forwarded to Color coating line.
- **Color Coating**

In this step, GI or GL sheets are coated with the paint which is according to the customer requirement. The standard combination which JSW offers to the customer is Blue colour on up side and white colour on down side. After colour coating, sheets are coated with film guards, but it is done only when customers demands for it. The color coated sheets are named as Pre Painted Galvanized Iron (PPGI) or Pre Painted Galvalume (PPGL). These are the finished products which if needed forwarded for cutting and corrugation.

Color coated steel sheet is widely used in the construction industry, household appliances and transportation for the construction industry is mainly used for steel plants, airports, warehouses and refrigeration and other industrial and commercial building roofs walls and doors etc.

PROBLEM STATEMENT

JSW Steel Ltd. facing regular issues in their mechanical maintenance activities due to various reasons such as general problem solving techniques, communication from one operator to another, material handling techniques, standard operating life of equipments etc. This was accounting into effects such as maximum resolution time on any issue in color coating line, high maintenance cost of sub equipments of finished goods line.

RESEARCH QUESTIONS

a) Does improving reliability of a system help the organization to improve its productivity?
b) What factors that an organization should take into consideration to develop an effective maintenance schedule?

OBJECTIVES OF STUDY

1. To address issues in lack of integration in maintenance strategy, resource utilization, optimum utilization of machineries.
2. To analyze and study various kinds of defects that is occurring in the system with the help of Reliability Management Practices and advanced TQM techniques.
3. To correct the communication process at the time of issue resolution in case of system failure.

SAMPLING SIZE

Data Collection: Machine breakdown events and reason behind that breakdown is collected from Mechanical maintenance log book of color coating line for the period of 14 months (April-2009 to May-2010)

RESEARCH METHODOLOGY

Breakdowns of degreasing units in Color Coating Line (II):

SR.	DATE	DELAY		TOTAL	CUM.	EQP.	REASON	ACTION TAKEN
1	24.07.2009	8	8.45	45	45	Alkali #1	Dent was formed from damaged rubber	Damaged rubber cutting done
2	07.08.2009	11.4	12.2	40	85	Alkali #1	Fold mark observed	Bottom roll changed
3	24.09.2009	3.5	4.05	15	100	Alkali#1	Dent formed due to damaged rubber	Roll by-passed
4	14.10.2009	23.3	23.5	20	120	Alkali#1	Fold mark observed from exit sq. roll	Squeeze roll by-passed
5	20.11.2009	17.3	18	30	150	Alkali#1	Fold created from exit sq roll	Roll changed
6	06.01.2010	2.5	3.1	20	170	Alkali#1	bottom rollo/s bearing damaged	Bearing changed

7	02.09.2009	17.2	18.4	80	250	Alkali#2	Edge wavy formation observed from rolls	Squeeze rolls changed
8	19.10.2009	0.35	0.55	20	270	Alkali#2	Fold mark observed from exit sq. roll	Squeeze rolls changed
9	07.11.2009	15.5	15.6	10	280	Alkali#2	Fold was created from entry sq.roll	Roll by-passed and changed
10	14.12.2009	21.2	21.3	15	295	Alkali#2	Fold mark observed frm exit pair sq roll	Roll by passed
11	08.01.2010	15.2	15.3	15	310	Alkali#2	Exit 1st pair bottom roll's d/s bearing was damaged	Bearing changed
12	07.08.2009	10.2	10.4	15	325	Alkali#1	Fold mark observed	Squeeze roll pressure adjusted
13	17.09.2009	11.1	11.2	15	340	Brushing unit	Fold mark observed from exit sq. roll	Squeeze rolls by-passed
14	17.09.2009	16	17	60	400	Brushing unit	Fold mark observed from exit sq. roll	Squeeze rolls changed
15	20.10.2009	18.2	18.4	20	420	Brushing unit	Entry sq roll pair's bottom roll's brg was damaged	Bearing changed
16	21.11.2009	13	13.1	10	430	Brushing unit	Fold was created from exit sq roll	Roll by-passed
17	05.12.2009	0.05	1.05	60	490	Brushing unit	Dent was forming from exit sq roll	Sq roll pair changed
18	05.06.2009	12.4	14.2	100	590	Alkali#1	Alkali#1's exit side bottom squeeze roll damaged	Roll changed
19	20.06.2009	8.3	8.5	20	610	Degreasing	Edge wavy formation observed	Pressure adjusted
20	22.06.2009	6.15	6.4	25	635	Degreasing	Dent formed due to rubber was peeled off	Rubber cutting done
21	02.11.2009	18.1	18.2	10	645	Hot rinse#1	Fold was created from entry sq.roll	Roll by-passed
22	02.11.2009	20.1	20.2	10	655	Hot rinse#1	Fold was created from exit sq.roll	Roll by-passed
23	30.11.2009	19.2	20	45	700	Hot rinse#2	Water carry over observed	Roll changed
24	24.12.2009	17.3	18.3	60	760	Hot rinse#2	Side tracking observed	H.R.#2 exit pair by passed
25	29.12.2009	20.2	20.2	5	765	Hot rinse#2	Side tracking observed	H.R.#2 exit pair by passed
26	30.04.2009	23.5	0.2	30	795	Hot rinse#1	Fold mark observed	Squeeze roll opened and by-passed
27	23.05.2009	5.5	6	10	805	Hot rinse#1	Fold mark observed	Squeeze roll opened and by-passed

28	24.07.2009	7	7.45	45	850	Hot rinse#1	Dent was formed from damaged rubber	Damaged rubber cutting done
29	27.07.2009	9.25	9.4	15	865	Hot rinse#1	Fold mark observed	Roll by-passed
30	07.05.2009	11.1	11.3	25	890	Hot rinse#2	Its pair's squeeze roll was damaged	Roll changed
31	16.08.2009	15	15.2	15	905	Hot rinse#2	Fold mark observed	Squeeze roll pressure adjusted

Breakdowns of Degreasing Unit of CCL-II for F.Y. 2009-10

Total Loss due to breakdown : 905 mins (from above analysis)
Total loss in production of CCL-II because of all equipments: 7079 mins (mechanical maintenance log book)

		Hours
1 year (Span)	365 * 24	8760
Total hours when production is stopped	7079/60	117.98
Hours when degreasing unit is not working	905/60	15.08
Total hours when CCL II is available for production	(8760-117.98)	8642.02
Total Time (from degreasing unit's point of view)	Time when degreasing unit is available + time when degreasing unit is not working	
Time (T)	8642.02 + 15.08	**8657.1 Hours**
No of failures in 1 year	31	
Failure Rate (λ)	31/8657.1	0.00358
MTTR	15.08/31	0.486 = **29 mins**
MTBF = 1/λ	(1/0.00358)	279.32 = **11.65 Days**

Reliability parameters Calculations of degreasing unit

- **Breakdowns of Quench Tank Unit of CCL-II for FY. 2009-10:**

SR.	DATE	DELAY		TOTAL	CUM	EQPT.	REASON	ACTION TAKEN
1	10.04.2009	8.05	8.15	10	10	Q T # 1	Water carry over obserevd	Squeeze roll pressure adjusted
2	15.04.2009	21.05	21.2	10	20	Q T # 1	Water carry over obserevd	Squeeze roll pressure adjusted
3	16.04.2009	10	13	180	200	Q T # 1	Side tracking occurred	Squeeze rolls changed and o/s cylinder changed

4	20.04.2009	18.3	19	30	230	Q T # 1	Top squeeze roll's o/s bearing was damaged	Top roll changed
5	03.07.2009	10	10.2	20	250	Q T # 1	Bottom roll's d/s bearing damaged	Bearing changed
6	03.07.2009	20.4	22	80	330	Q T # 1	Bottom roll damaged	Roll changed
7	10.07.2009	3.5	4.05	15	345	Q T # 1	Water carry over observed	Squeeze roll pressure adjusted
8	12.07.2009	15.15	15.5	30	375	Q T # 1	Water carry over observed	Squeeze roll pressure adjusted
9	22.07.2009	5	5.1	10	385	Q T # 2	Water carry over observed	Squeeze roll pressure adjusted
10	30.07.2009	13.1	13.3	20	405	Q T # 1	Water carry over observed	Squeeze roll pressure adjusted
11	17.08.2009	1.4	3.1	90	495	Q T # 2	Bottom roll's d/s brg damaged	Brg changed
12	19.08.2009	19.45	20.5	60	555	Q T # 2	Bottom roll's o/s brg damaged	Brg changed
13	24.08.2009	13.4	15	80	635	Q T # 2	Bottom squeeze roll damaged	Roll changed
14	24.08.2009	15.05	17.3	145	780	Q T # 2	Grease patches observed	Water drained and re-filled
15	13.09.2009	5.4	6.2	40	820	Q T # 1	Black particles formed from support roll	Roll by-passed
16	20.09.2009	13.3	13.6	25	845	Q T # 1	Its top squeeze roll was damaged	Roll changed
17	14.11.2009	6.3	7	30	875	Q T # 1	Water carry over observed	Sq roll pressure increased
18	14.11.2009	8.01	10.2	140	1015	Q T # 1	Water carry over observed	Sq rolls are burnt, they are replaced
19	15.11.2009	3.15	3.35	20	1035	Q T # 2	Water carry over observed	Sq roll pressure increased
20	03.12.2009	9.3	10.2	45	1080	Q T # 1	o/s bearing damaged	Bearing changed
21	26.12.2009	5.3	5.45	15	1095	Q T # 2	Water carry over observed	Sq roll pressure adjusted
22	26.12.2009	7.4	8	20	1115	Q T # 2	Bottom rolls d/s brg changed	Brg changed
23	05.01.2010	21.5	22.2	30	1145	Q T # 2	Water carry over observed	Squeeze roll pressure increased
24	07.01.2010	9.15	10.5	90	1235	Q T # 2	Water carry over observed	Sq roll pair changed
25	09.01.2010	22.2	22.4	20	1255	Q T # 1	Water carry over observed	Controlled by adjusting squeeze roll pressure
26	18.02.2010	0.5	1.15	25	1280	Q T # 2	1st pair's bottom roll's d/s bearing was damaged	Bearing changed
27	20.02.2010	15.3	15.3	120	1400	Q T # 1	Squeeze roll were damaged	Pair changed

28	09.03.2010	0.15	0.45	30	1430	Q T # 1	Squeeze roll edge wavy formation	Sq roll pair rotated manually

Breakdowns of Quench Tank Unit for F.Y. 2009-10

1) Quench Tank Unit of CCL-II
Reliability Parameters Calculations

		Hours
1 year (Span)	365 * 24	8760
Total hours when production is stopped	7079/60	117.98
Hours when Quench Tank unit is not working	1430/60	23.83
Total hours when CCL II is available for production		8642.02
No of failures in 1 year	28	
Failure Rate (λ)	28/8665.85	0.00323
MTTR	23.83/28	**0.851 = 51.1 mins**
MTBF = 1/λ		**309.59 = 12.89 days**
Total Time	Time when Quench Tank unit is available + time when Quench Tank unit is not working	
Time (T)	8642.02 + 23.83	8665.85

7079 min - overall delay of CCL-II
1430 min - Delay of Quench Tank Unit
29 - No. of stoppages due to CCL-II ofQuench Tank Unit
8665.85 is time when degreasing is avilable for production (6842.02+23.83)

Reliability parameters calculations of Quench Tank unit

DEFECT ANALYSIS

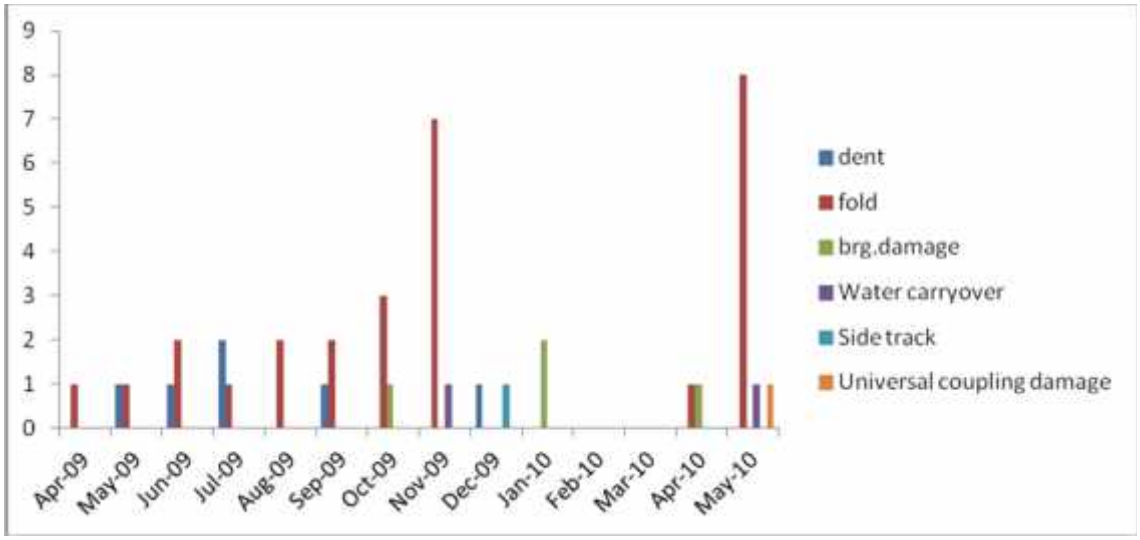
1) Degreasing Unit
Below are the findings of all the errors of degreasing unit of CCL-II from the period April-2009 to May-2010. The frequency trend of occurrence of error is analyzed against the total production of that particular month. It is given as below,

	Total Production	6401	8153	7069	7323	6427	7272	6452	6297	6710	6120	5663	4801	6910	5945
	Domestic	777	635	657	547		1690	1020		1488	1823	1220	1525	1061	1310
Sq Roll No	**Error**	**Apr-09**	**May-09**	**Jun-09**	**Jul-09**	**Aug-09**	**Sep-09**	**Oct-09**	**Nov-09**	**Dec-09**	**Jan-10**	**Feb-10**	**Mar-10**	**Apr-10**	**May-10**
1	dent				1										
	fold														1
	brg.damage														
	Water carryover														
	Side track														
	Universal coupling damage														
2	dent			1			1								
	fold			1		2		2	2						
	brg.damage										1			1	
	Water carryover														
	Side track														
	Universal coupling damage														
3	dent														
	fold														3
	brg.damage							1							
	Water carryover														
	Side track														
	Universal coupling damage														
4	dent									1					
	fold			1			2		2						2
	brg.damage														
	Water carryover														
	Side track														
	Universal coupling damage														
5	dent														
	fold							1						1	1
	brg.damage										1				
	Water carryover														1
	Side track														
	Universal coupling damage														

	Total Production	6401	8153	7069	7323	6427	7272	6452	6297	6710	6120	5663	4801	6910	5945
	Domestic	777	635	657	547		1690	1020		1488	1823	1220	1525	1061	1310
Sq Roll No	Error	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10	Apr-10	May-10
6	dent														
	fold								2						2
	brg.damage														
	Water carryover														
	Side track														
	Universal coupling damage														
7	dent				1										
	fold	1	1		1				1						
	brg.damage														
	Water carryover														
	Side track														
	Universal coupling damage														
8	dent														
	fold														
	brg.damage														
	Water carryover								1						
	Side track									1					
	Universal coupling damage														
9	dent		1												
	fold														
	brg.damage														
	Water carryover														
	Side track														
	Universal coupling damage														
Total	dent	0	1	1	2	0	1	0	0	1	0	0	0	0	0
	fold	1	1	2	1	2	2	3	7	0	0	0	0	1	8
	brg.damage	0	0	0	0	0	0	1	0	0	2	0	0	1	0
	Water carryover	0	0	0	0	0	0	0	1	0	0	0	0	0	1
	Side track	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Universal coupling damage	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Defect Analysis of Degreasing Unit for period April-09 to May-10

Frequency Analysis of above errors is plotted against respective months,



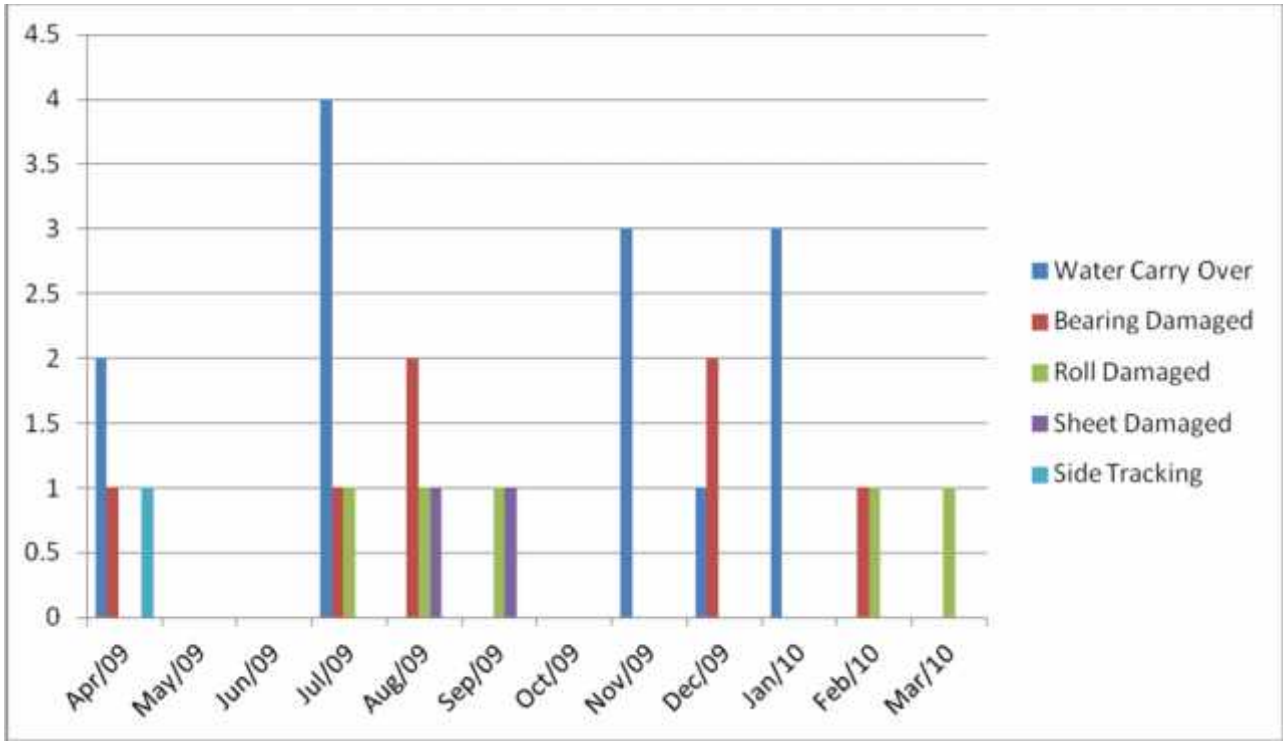
Frequency Analysis of errors of degreasing unit

2) Quench Tank Unit

Quench Tank Unit		Total Production	6401	8153	7069	7323	6427	7272	6452	6297	6710	6120	5663	4801
		Domestic	777	635	657	547		1690	1020		1488	1823	1220	1525
Equipment	Sq Roll No	Error	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10
Quench Tank 1	1	Water Carry Over	2			3				2		1		
		Bearing Damaged	1			1					1			
		Roll Damaged				1		1					1	1
		Sheet Damaged						1						
		Side Tracking	1											
Quench Tank 2	1	Water Carry Over				1				1	1	2		
		Bearing Damaged					2				1		1	
		Roll Damaged					1							
		Sheet Damaged					1							
		Side Tracking												
Total		Water Carry Over	2	0	0	4	0	0	0	3	1	3	0	0
		Bearing Damaged	1	0	0	1	2	0	0	0	2	0	1	0
		Roll Damaged	0	0	0	1	1	1	0	0	0	0	1	1
		Sheet Damaged	0	0	0	0	1	1	0	0	0	0	0	0
		Side Tracking	1	0	0	0	0	0	0	0	0	0	0	0

Defect Analysis of Quench Tank Unit for period April-09 to May-10

Frequency Analysis of above errors is plotted against respective months,

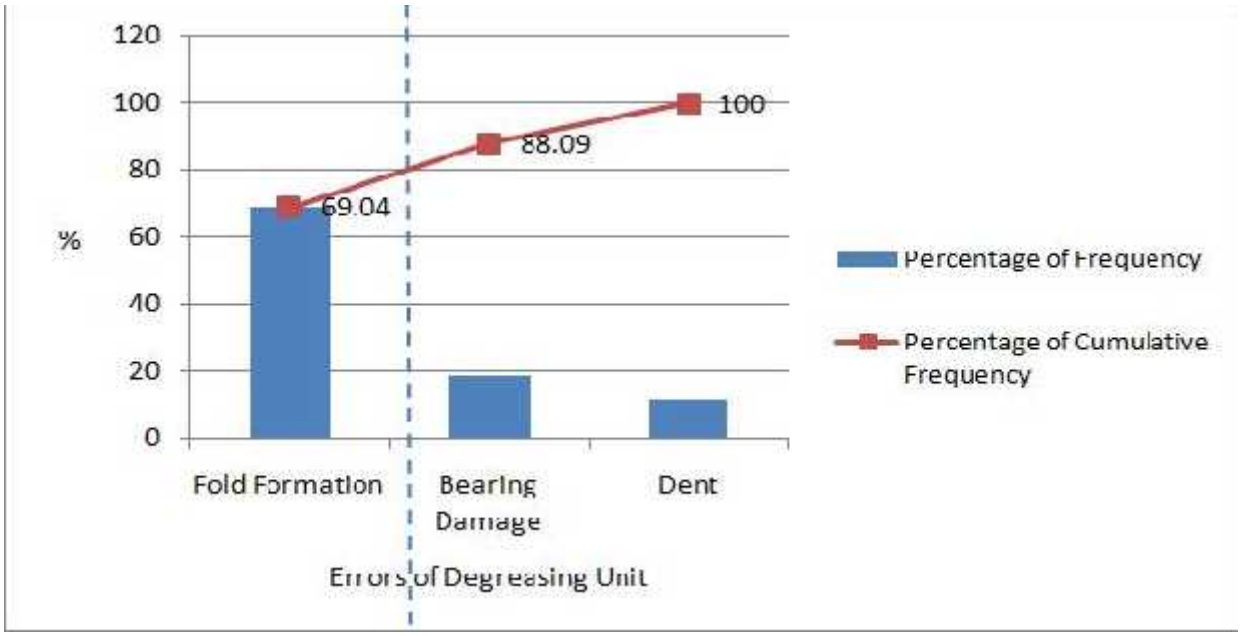


Frequency Analysis of errors of quench tank unit

- **Pareto Analysis of errors in Degreasing Section**

Problem	**Frequency**	**Percentage of Frequency**	**Cumulative Frequency**	**Percentage of Cumulative Frequency**
Fold Formation	29	69.04	29	69.04
Bearing Damage	8	19.04	37	88.09
Dent	5	11.9	42	100

Pareto Chart for Degreasing Unit



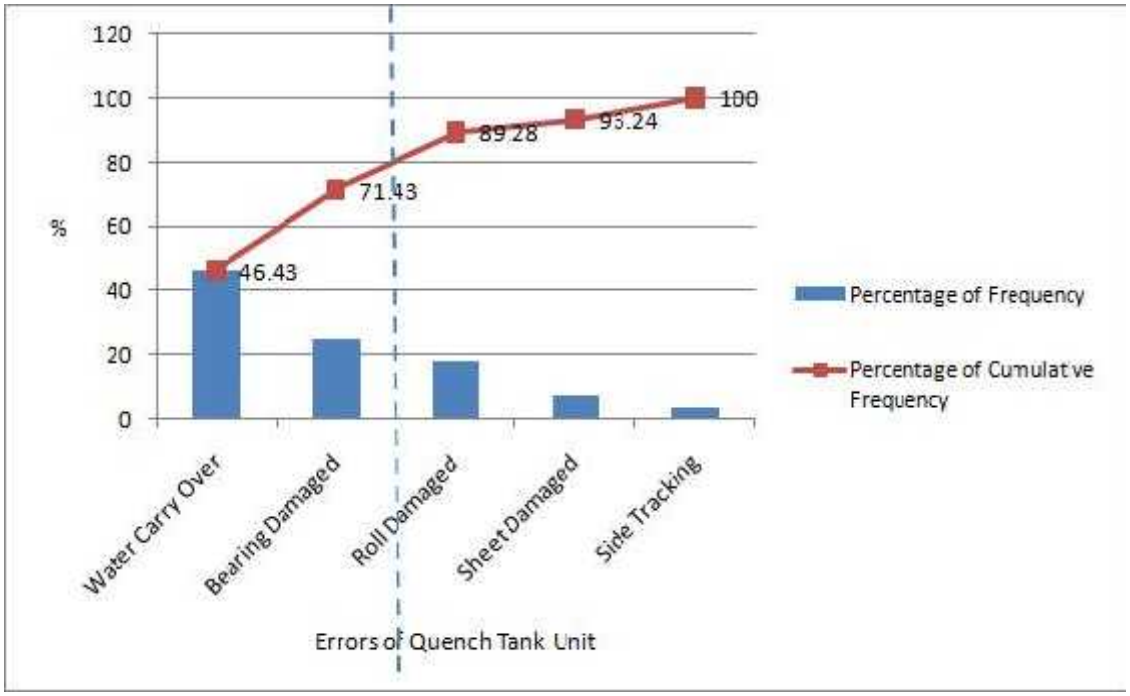
Pareto Graph of Degreasing Unit

From above graph it can be concluded that, the production which was affected due to degreasing section, most of the times it is due to fold formation. With reference to mechanical maintenance log book, the major reasons for fold formation are damage of squeeze rolls, bearing problem, type of input material.

- **Pareto analysis of errors in Quench Tank Section**

Problem	Frequency	Percentage of Frequency	Cumulative Frequency	Percentage of Cumulative Frequency
Water Carry Over	13	46.43	13	46.43
Bearing Damaged	7	25	20	71.43
Roll Damaged	5	17.85	25	89.28
Sheet Damaged	2	7.14	27	93.24
Side Tracking	1	3.57	28	100

Pareto Chart for Quench Tank Unit

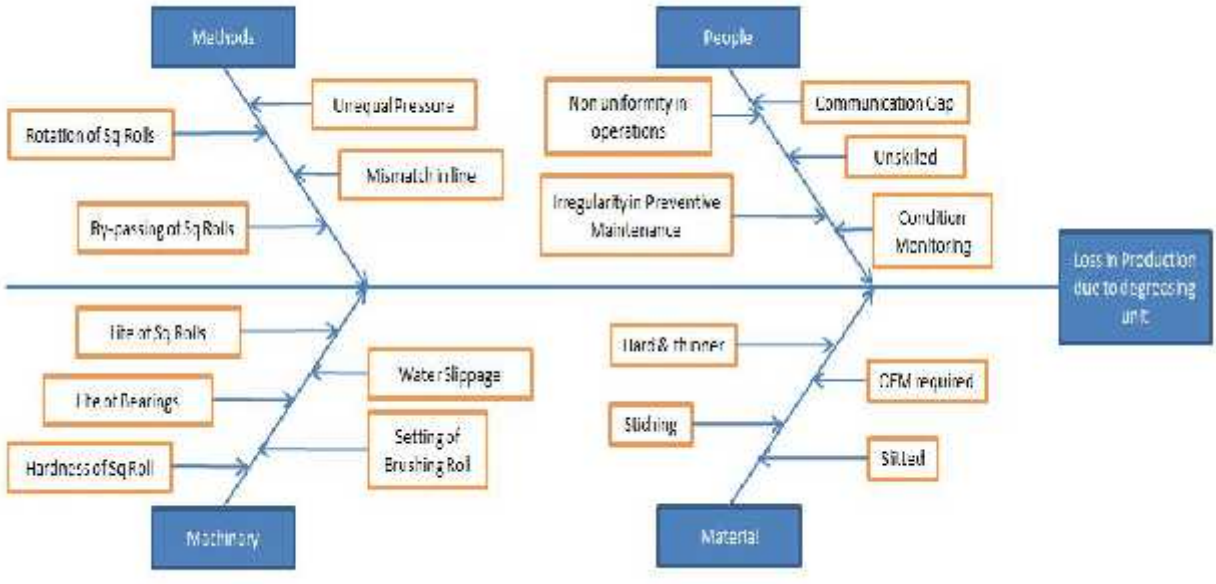


Pareto Graph for Quench Tank Unit

From above graph it can be concluded that, when the production of CCL-II unit was affected due to Quench Tank Unit, the major reasons were Water Carryover and bearing damaged.

Cause and Effect Analysis

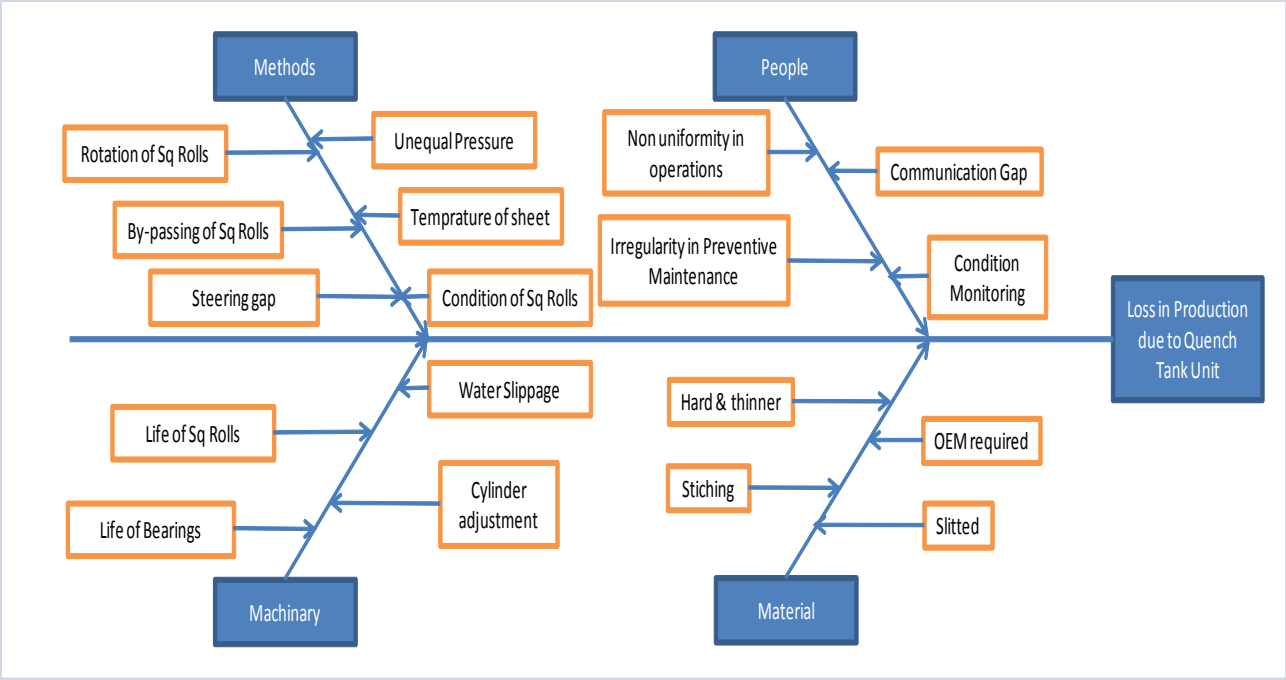
a) Degreasing Unit



Cause & Effect Diagram for Degreasing Unit

To improve the productivity of CCL-II unit, above areas from degreasing unit need to be handled separately. Also point to be noted is majority of above reasons are root cause for fold formation on sheets.

b) Quench Tank Unit



Cause & Effect Diagram for Quench Tank Unit

To improve the productivity of CCL-II unit, above areas from quench tank unit needs to be handled separately. Also point to be noted is majority of above reasons are root cause for water carry over, bearing damage.

FINDINGS

1. As MTBF values of degreasing unit and quench tank unit are 11.65 days and 12.89 days respectively, squeeze rolls setting and brushing unit settings need to be reviewed after 10 days on regular basis. This will help to avoid issues in squeeze rolls.
2. Informative and practical training sessions should be organized for mechanical operators to elaborate them the standard operating procedure while executing maintenance activities. This will help the organization to focus on reducing MTTR value.
3. Sq Roll pairs of degreasing unit should be replaced on monthly basis.
4. Preventive maintenance activities should be planned well in advance and the frequency should be constant.
5. Company should not be totally dependent on RMS (Raw Material Shortage) time for maintenance activities.
6. All details of changing squeeze roll pairs should be maintained in Mechanical Maintenance Log Book.
7. Bearing change details are found to be missing at the time of changing the squeeze rolls pair. Mechanical Operator will have to focus on maintaining these details.
8. While replacing bearings, please note the changes, i.e. which side bearing got replaced either it top operator side or top drive side or bottom operator side or bottom drive side bearing.
9. Setting of brushing roll need to be reviewed, because its position is not suitable for smooth transfer of sheet through degreasing unit. Sheet has faced frequent damage issues because of these missing settings.
10. Bearings and squeeze roll pairs needs to be monitored against their standard operation life.

11. Observing fold marks on sheet is a major problem from degreasing unit end, solutions such as bypassing squeeze rolls need to be revised because it is an invitation to other problems such as water carryover.
12. In case of quench tank section, water carryover is a frequent problem, most of the times it is observed in Quench Tank 1 unit, so this needs to be handled on priority.
13. For quench tank section, temperature of sheet must be monitored on regular basis, because overheating squeeze roll is getting burnt.
14. Again in case of maintenance activities of quench tank unit, details of bearing change are missing in the mechanical maintenance log book.
15. If an officer founds a bearing or squeeze roll pair damaged, then it should get replaced on that day only because many times it is observed that it is only noted and no action is taken from Mechanical end on that day, and after a day or two it got replaced.

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