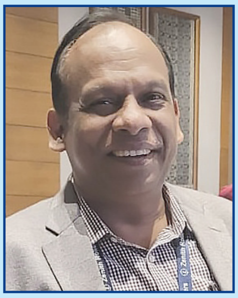
ISSN: 0379-5462
IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association
Vol. 37, E1, 2025, p. 169-174

Machine reliability improvement with use of Artificial Intelligence



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Abstract:

In the ever-evolving landscape of industrial automation, the integration of Artificial Intelligence (AI) has emerged as a game-changer for predictive maintenance and operational efficiency. This paper presents a case study on the implementation of AI technology to monitor bearing failures and enhance Overall Equipment Efficiency (OEE) in our paper mill. Among our six paper machines, PM-6—boasting the highest production capacity of approximately 500 TPD—was selected for this AI-driven transformation.

We as WCPM also use these AI tools on our Paper Machine with respect to real time Data monitoring and timely action. Thus, impact positively on machine performance on critical parameters as:

• Online bearing - Critical areas • Bearing Vibration monitoring
• LR/HR ratio for monitor shock impact • Bearing Health score

Further in this paper, we try to emphasise our monitoring methodology as a case study for improving our machine productivity.

Keywords: *Vibration Monitoring, LR/ HR ratio, Health score*

Introduction

Paper manufacturing is a process industry where lot of parameters related to process and maintenance works together to get final product. All machine related conditions and parameters work with variance (Minor/ Major), which impact the machine productivity and efficiency.

In current competitive environment where lot of high-speed machines are running, so machine conditions are directly impacting its reliability resulting in overall machine performance.

Machine performance is depending on following major indicators –

- Operating parameters
- Equipment conditions
- Parameter synchronisation as per quality

Usually, all process parameters are monitored through DCS and online Scanners. All machine conditions are visible on DCS system except some critical equipment conditions i.e. bearings conditions, temperatures

At West Coast Paper Mills - Dandeli, Average overall WCPM production is 1000 MT/ day, against that 50 % production is from PM6, which is running at 1100 MPM speed. We were continuously facing issue of low bearing life at Tandem Shoe Press section even with QCS and continuous monitoring system, forced to reduce the speed to 980MPM. Due to this unplanned break down, machine productivity as well as R&M expenses affected badly.

Last four-year press section bearing failure data is shown in Figure 1. Figure clearly indicating bearing failure are in increasing trends.

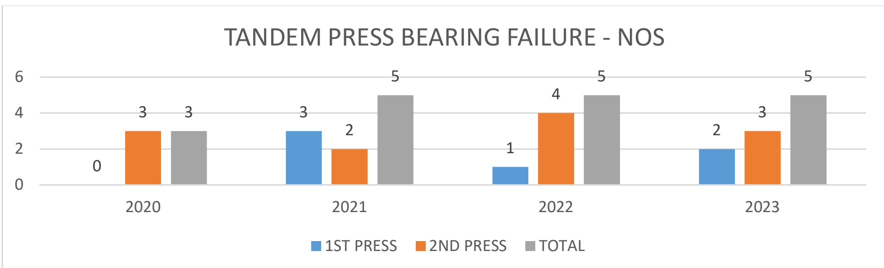

Figure – 1, PM6 – Press part Bearings failure data

Figure 2 - Bearing failure defect photograph

Even with different available resources for minimizing the losses, we have increased checking frequency for manual monitoring system, machine conditions and parameters. Still, we could not succeed to minimize bearing failure.

Even after OEM support and modification, we tried to increase machine speed at different level but failed to control bearing break down. After failure analysis, bearing failures are due to various reasons.

- Roller defect
- Inner and outer race pitting
- Cage defects

Different types of Bearing defects on our machine and real images are shown in Figure 2.

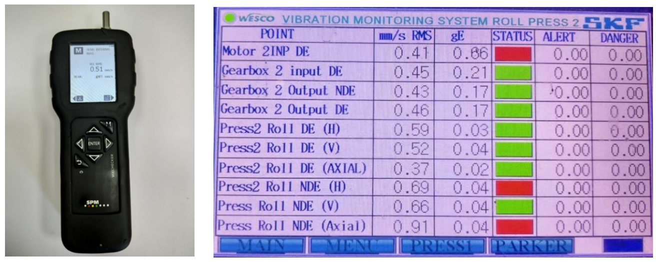

Figure 3 – WCPM - Press Part Bearing Monitoring – SKF , Hand hold device - SPM

Initially WCPM was using trouble shooting method like, Bearing parameter monitoring, vibration and temperature. In bearing failure period, we were using machine monitoring device and method for bearings condition i.e. SKF Offline Bearing monitoring and SPM hand hold device for vibration measurement. Figure 3 is showing offline hand hold device for vibration measurement and SKF machine monitoring screen for online vibration data.

For minimizing the bearing failure, we increase the checking frequency for manual vibration and temperature in Press section. Figure 4 is showing the data related to temperature and operating condition.

	2ND PRESS BEARING MONITORING																	
DATE	TIME	QUALITY/ GSM	SPEED	S 2 SPEE	LINE LOAD	LUBRICATION OIL P/P		2ND PRESS BEARING						1ST PRESS BEARING				
			MPM	MPM	N/M	NASH	TEMPARATURE	SYSTEM PRESSURE	TEMP NDE	DELTA TEMP	TEMP DE	DELTA TEMP	RETURN LINE TEMP 2ND	TEMP NDE		TEMP DE	DELTA TEMP	RETURN LINE TEMP 1ST
										WRT NDE		WRT DE						
25/08/23	7.00AM	B2B COPIER	962	934	670	6 (34%)	43.25	19	48.68	5.43	49.36	6.11	56.24	46.93	3.68	45.31	2.06	54.94
	8.00AM	B2B COPIER	962	934	670	5 (35%)	43.25	19	48.72	5.47	49.44	6.19	56.27	46.98	3.73	45.45	2.2	54.97
	9.00AM	B2B COPIER	962	934	670	5 (35%)	43.25	19	48.78	5.53	49.53	6.28	56.3	47.07	3.82	45.57	2.32	54.97
	10.00AM	B2B COPIER	962	934	670	6 (36%)	43.25	19	48.76	5.51	49.76	6.51	56.39	47.3	4.05	45.91	2.66	55.12
	11.00AM	B2B COPIER	962	934	670	6 (34%)	43.25	19	48.87	5.62	49.76	6.51	56.39	47.33	4.08	45.86	2.61	55.03
	12.00AM	B2B COPIER	970	942	670	6 (34%)	43.22	19	49.04	5.82	49.91	6.69	56.53	47.48	4.26	46.15	2.93	55.23
	1.00PM	B2B COPIER	975	947	670	6 (34%)	43.25	19	49.10	5.85	50.08	6.83	56.62	47.62	4.37	46.41	3.16	55.29
	2.00PM	B2B COPIER	975	947	670	5 (37%)	43.28	19	49.07	5.79	50.23	6.95	56.71	47.8	4.52	46.7	3.42	55.4
	3.00PM	B2B COPIER	980	952	670	5 (34%)	43.28	19	49.21	5.93	50.40	7.12	56.82	47.94	4.66	46.58	3.3	55.55
	4.00PM	B2B COPIER	975	948	670	5 (33%)	43.25	19	49.47	6.22	50.34	7.09	56.73	48.06	4.81	46.93	3.68	55.46
	5.00PM	B2B COPIER	975	948	670	6 (33%)	43.25	19	49.44	6.19	50.34	7.09	56.74	48.06	4.81	46.87	3.62	55.43
	6.00PM	B2B COPIER	975	948	670	6 (34%)	43.28	19	49.36	6.08	50.20	6.92	56.71	47.91	4.63	46.75	3.47	55.43
	7.00PM	B2B COPIER	975	948	670	6 (35%)	43.22	19	49.36	6.14	50.02	6.80	56.62	47.77	4.55	46.58	3.36	55.4
	8.00PM	B2B COPIER	975	948	670	7 (33%)	43.25	19	49.18	5.93	49.94	6.69	56.59	47.59	4.34	46.26	3.01	55.32
	9.00PM	B2B COPIER	975	948	670	7 (33%)	43.25	19	49.21	5.96	49.79	6.54	56.59	47.45	4.2	46.06	2.81	55.29
	10.00PM	B2B COPIER	975	948	670	6 (35%)	43.25	19	49.07	5.82	49.76	6.51	56.56	47.45	4.2	45.97	2.72	55.26
	11.00PM	B2B COPIER	975	948	670	6 (35%)	43.22	19	49.01	5.79	49.68	6.46	56.53	47.33	4.11	45.91	2.69	55.26
	12.00PM	B2B COPIER	975	948	670	6 (34%)	43.22	19	48.92	5.70	49.68	6.46	56.53	47.33	4.11	45.89	2.67	55.26
	1.00AM	B2B COPIER	975	948	670	5 (35%)	43.25	19	48.89	5.64	49.62	6.37	56.53	47.22	3.97	45.74	2.49	55.23
	2.00AM	B2B COPIER	975	948	670	5 (35%)	43.25	19	48.92	5.67	49.59	6.34	56.47	47.19	3.94	45.68	2.43	55.17
	3.00AM	B2B COPIER	975	948	670	6 (36%)	43.22	19	48.87	5.65	49.59	6.37	56.47	47.19	3.97	45.71	2.49	55.17
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	5.00AM	B2B COPIER	975	948	670	6 (34%)	43.25	19	48.78	5.53	49.47	6.22	56.45	47.04	3.79	45.63	2.38	55.12
	6.00AM	B2B COPIER	975	948	670	5 (37%)	43.25	19	48.78	5.53	49.5	6.25	56.45	47.01	3.76	45.54	2.29	55.14

Figure - 4, PM6 – Press Part Bearing Temperature and Oil lubrication data

All these monitoring parameters were not available on continuous basis in DCS system.

To improve this monitoring and to get more data we install SKF online monitoring sensor

- o Press part bearing housing for press rolls (Front side/ Back side)
- o Gear box
- o Drive motor Bearing Temperature
- o Lubrication oil inlet and out temperature observed on hourly basis

Even after implementation of above, we could not find out clear picture of bearing failure as data were not available on real time basis. So, route cause was not found.

After lot of trial and brainstorming and data analysis, we concluded that due to non-availability of real time data for vibration, exact reason of bearing failure is not clear. To overcome this problem, we decided to install online real time vibration monitoring system for press part.

Here AI (Artificial Intelligence) role comes for close monitoring of controlling parameters within required limit.

Artificial intelligence is the simulation of human intelligence processes by machines especially computer systems. Today, the amount of data that is generated by process and machine are extensively recorded on system and is used to teach an AI application. AI can provide recommendations for the optimal configuration of control parameters on the paper machine based on statistics. (Ref-1)

The result corelate in a software application acts as a master controller for the paper machine reliability. It receives the data from the production process via a defined interface and instruct machine to operate in defined parameters.

For this we install AI based online monitoring system by **SPM – CONDMASTER RUBY 2022** from Jan 2024.

This is a new version of comprehensive analysis and diagnostic software CONDMASTER 2020.

SPM Ruby introduces a range of new improved functionality with AI and machine learning, adding new powerful feature and expanded functionality with more accurate condition monitoring with enhanced alerts generation system.

The Shock Pulse Method (SPM) is a technique for monitoring the condition of machines with rolling element bearings while rotating. It uses signals from the bearings to analyse the condition of the bearing surfaces and lubrication in this system.

SPM - LR/HR Method (Ref - 2) allows the precision analysis of oil film condition in the interface between the outer and inner races and contains calculation models for finding the optimal lubricant.

The shock pulse meter counts the rate of occurrence (incoming shock pulses per second) and varies the gain until two amplitude levels are determined:

- HR = high rate of occurrence, quantifying the shock carpet (approx. 1000 incoming shocks per second).
- LR = low rate of occurrence, quantifying the strong shock pulses (approx. 40 incoming shocks per second).

LR and HR are 'raw values', measured in dBsv (decibel shock value).

SPM LR/HR trends for Good, Poor Lubricated and Damaged Bearings are shown in Figure 5.

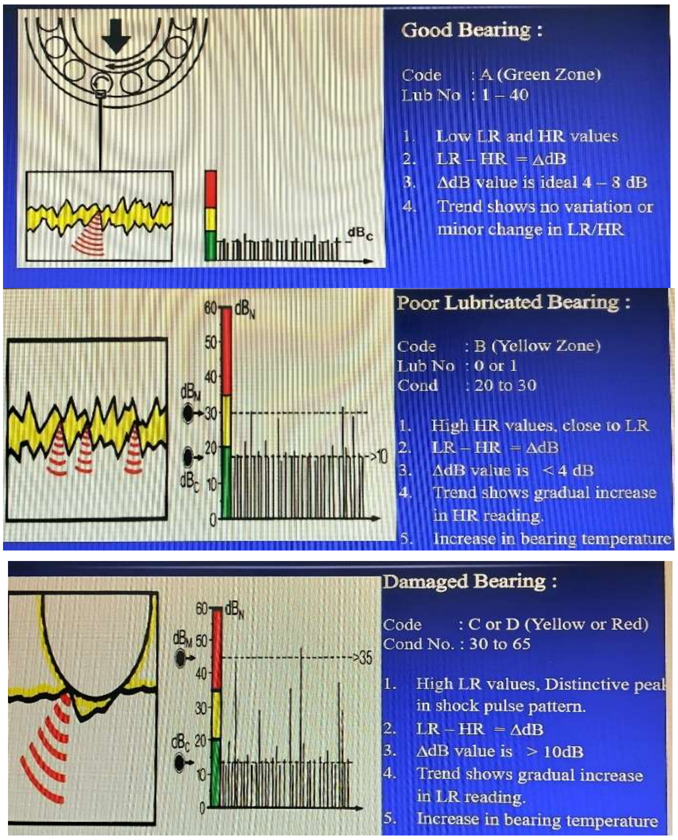


Figure 5 – SPM – Shock Pulse Method

SPM HD – High-Definition Shock Pulse (Ref-3) monitoring in a very broad RPM range, including ultra-low-speed applications (0.1 - 20 000 RPM range).

- The SPM method analyses the high-frequency shock waves generated by the bearing while it rotates.
- A transducer picks up the shock pulses and converts them into electric signals.
- The signals are processed to determine the rate of occurrence of shock pulses and the amplitude of the shocks.
- The SPM method uses a color-coded system to indicate the condition of the bearings.

Evaluation of reading works in following three steps

Trending

Collect SPM and Vibration data over a period of time

Plotting of graph and analysis of variation

Comprising

Comparing reading with similar machine

Compare SPM readings Vibration reading and analysis

Normalising

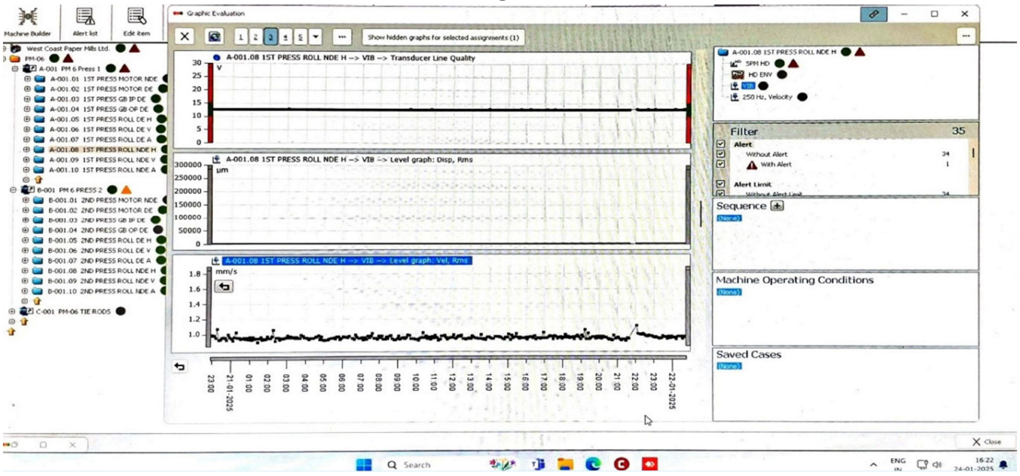
Establishing own limits (Good, Poor and Damaged) after hands on experience on same machine

Health Score

Health scores Is calculated by mathematical algorithms on collected base line data for individual machines. It represents in different colour gradient for evaluation. Gradient health score corresponds to a normalized floating points value from 0 to 1. Up 0.2 is coming in normal condition.

Online shock pulse method monitoring screen for normal and abnormal behaviour are shown in Fig 6.

Normal trends for 1st Press front side bearing



Abnormal trends for 1st Press front side bearing

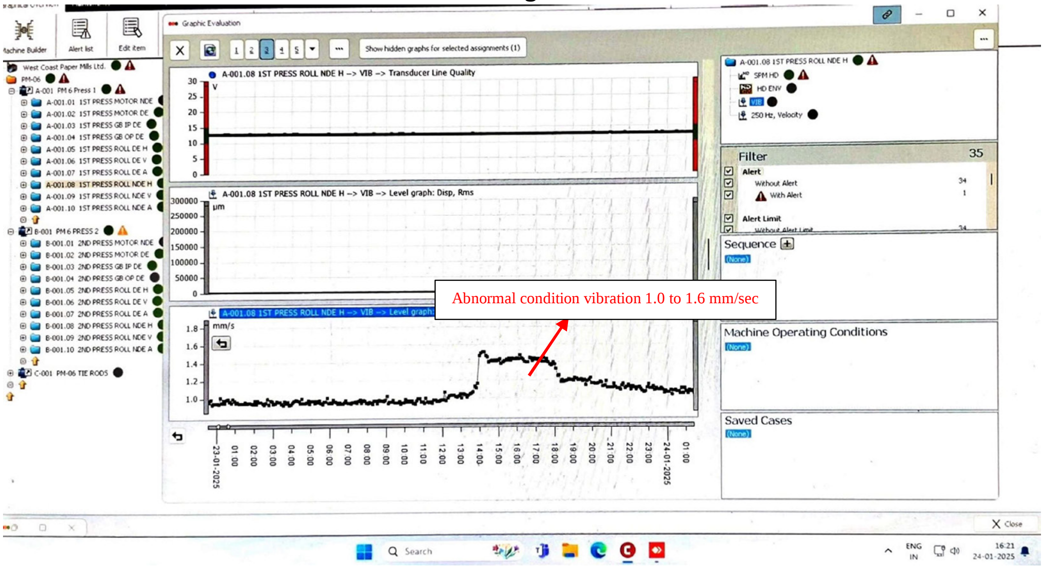


Figure 6, SPM – Shock Pulse Method monitoring screen

Currently online monitoring trends guides machine crew for further action.

Based on bearing behaviour trends, a summarise Alert system is developed, this generates alarm for abnormal behaviour and give summary report of generated alarms.

Figure – 7 and 8 shows bearing position tree view and summary alarm screen.

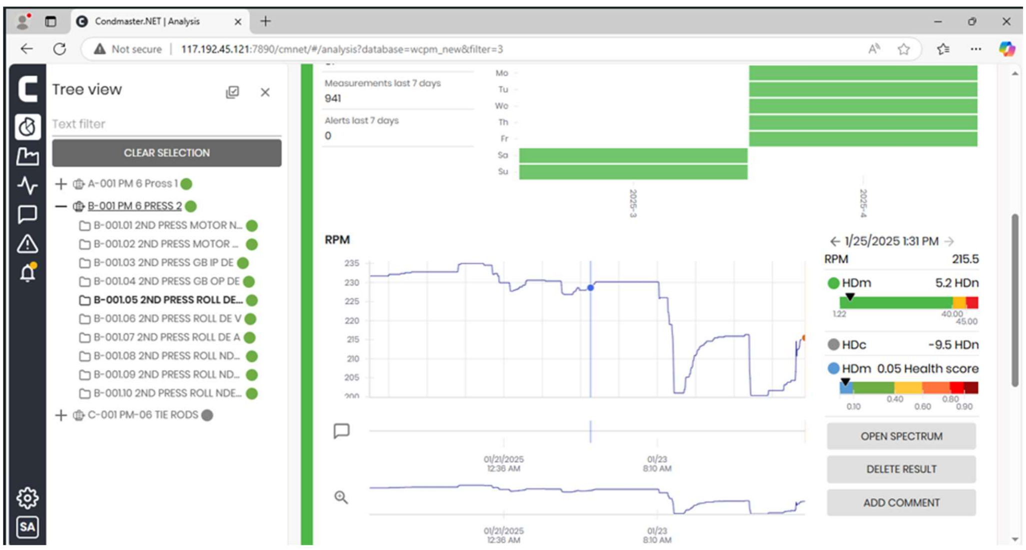


Figure 7, Condmaster Analysis - Tree View

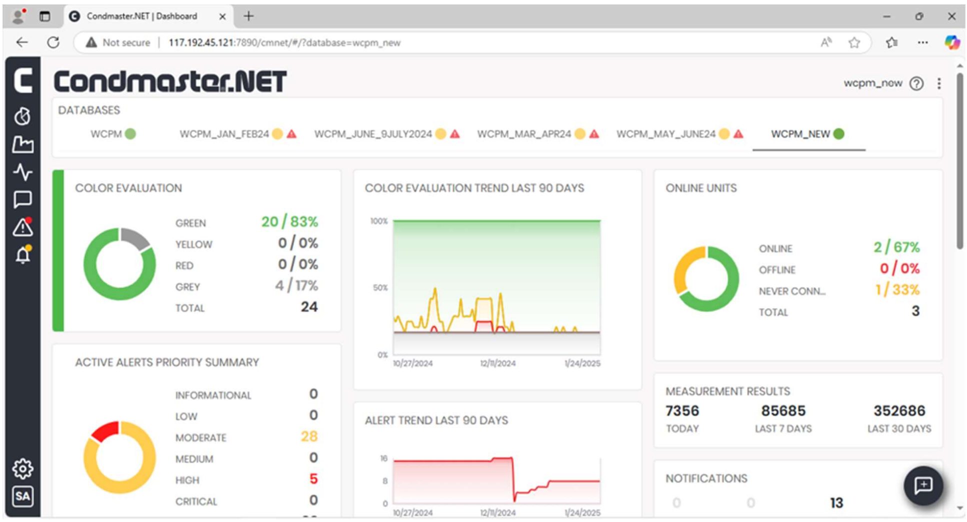


Figure – 8, Condmaster Summary Alert Screen

On basis of generated alarm, trends graph and colour spectrum, machine crew take decision for optimizing machine parameter like Oil flow, Press loads and machine speed, if required crew decide a planned shut to check the bearing internals condition to avoid unplanned break down.

To further strengthening this monitoring system, we also provided 4 numbers sensor on wire and press part cantilever beams.

Periodically we are also conducting high resolution videography for bearings and columns vibration. This videography is Iris MTM from RDI Technologies (Ref – 4) first of its kinds that allows user to see in real time – motion that is invisible by Human eyes. Iris M is unique technology that detects subtle movement and converts that movement to a visible level with the naked eye.

we have increased machine speed from 980 MPM to 1115 MPM and further we are planning to increase up to 1150 MPM.

RESULTS

With implementation of AI tools (Real time data input) and system Alarms, we are able to improve Machine reliability by minimizing the bearing failure, thus confidence developed in team to increase the machine speed gradually up to 1115 MPM. This also improve the Overall machine performance.

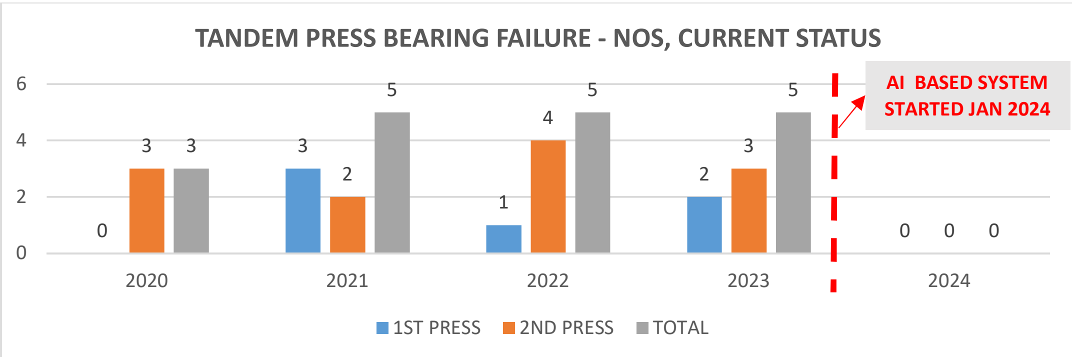


Figure - 10, Tandem PRESS Bearings failure – Current Status

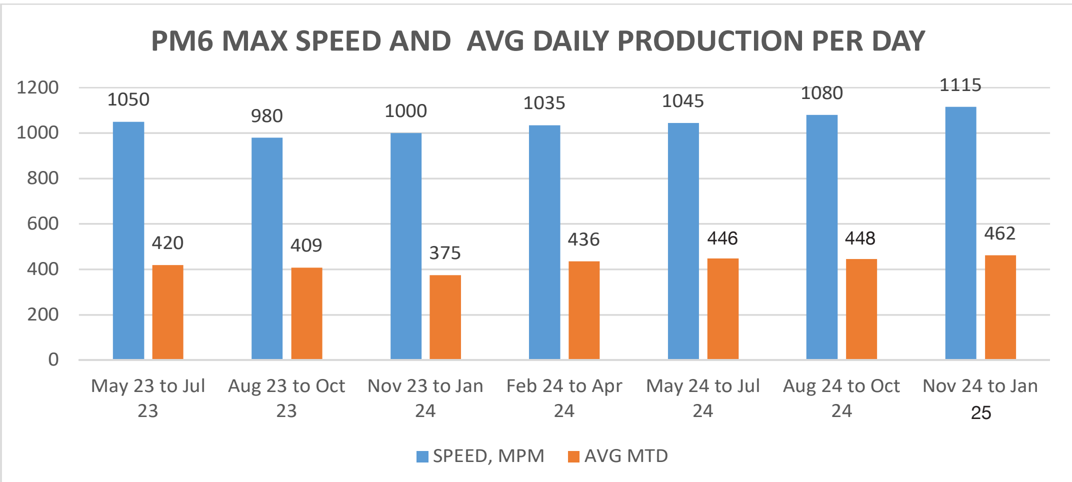


Figure - 11, PM6 Quarterly Average Daily Production, MT and Max Speed, MPM

Figure 10 is showing bearing failure trend.

Figure 11 shows Average per day production and speed increase after use of AI based approach.

CONCLUSION AND PATH FORWARD

The decision based on periodic data monitoring of any rotating machine may be sometimes misleading, as it is not giving the right picture in absence of the real time continuous data. So, need support of AI system, where decision is 100 % based on real time data monitoring and variances.

Our path forward is to use of AI based technology in production for improving machine productivity and reliability.

- Use of AI based prediction for optimising Refining parameter.
- Use of online and real time monitoring system for non-approachable areas. i.e. dry end rolls inside hood.

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