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# A Case Study on Reliability Improvement of New Bar Mill Stand Gearboxes

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Abstract: This paper describes the major work carried out in study & analyzing the critical reasons for failure of mill stand drive gearboxes that had occurred in New Bar Mill (Rebar Mill) in past 5 years. Suggest improvement measures and maintenance guidelines to decrease the probability of failure and hence develop an action plan for reliability improvement of New Bar Mill stand gearboxes. In the process, study on basics of gearbox and on rolling process of New Bar Mill has been done. Present production data analysis has been done for actual mill load condition. Based on present mill load data, current running service factor of gearboxes has been calculated. Many gearboxes of New bar mill stand found with low service factor than recommended as per AGMA standards. Accordingly, upgradation of mill drives gearboxes have been done for higher service factor and deployment of mill load alarm system to avoid any abnormal load on mill drive gearboxes has been carried out based on study.

### I. INTRODUCTION

The New Bar Mill was established in the year 2005 to produce long products i.e. TMT (Thermo Mechanically Treated) bars. It rolls billets having cross-section  $(150 \times 150)$  mm<sup>2</sup> and length 12m into TMT bars having a wide range of diameters i.e. 8mm,10mm and 12mm by the process of Hot Rolling as shown in fig.1. The mill has a total production output in FY'20 is about 1 MTPA against rated capacity of 0.6 MTPA. With the increase in production & speed of NBM mill over the years also increase in the torque load in mill drive gearboxes. Detailed analysis for recent failures happened in mill drive gearboxes especially in finishing mill stand no 14,15 & 16 and roughing mill stand no 1 & 3 has been carried out. During analysis present loading trend was also studied & found low service factor based on actual consumed peak torque in many stand gearboxes. The root cause for gearboxes failure was found to be under design of bearings with low service factor of gearboxes at consumed peak torque load.



Fig.1 OVERVIEW OF MILL STAND GEARBOXES

# II. ANALYSIS

In all the failures of Mill stand gearboxes of NBM in recent past, it has been observed that input shaft bearing was failed and in some cases input shaft gear teeth were also damaged due to misalignment generated post bearing failures. On Spet'2020, NBM stand no 1 vertical gearbox input shaft Non-drive end (NDE) spherical roller bearing was found damaged as inspected through inspection cover after hearing abnormal sound coming from gearbox.



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Heating marks were found on bearing rolling elements with cage breakage and few rolling elements came out from cage refer figure 2 & 3. This gearbox (overhauled) failed after giving service life of 1.1 year.



Fig.2 GA drawing of NBM stand 1 Gearbox



)amaged ca

In past also in 2019 abnormal sound was observed during rolling from stand no 16 gearbox. Mill was stopped for inspection of stand no. 16 gearbox by opening the inspection covers and it was found that input pinion shaft NDE spherical roller bearing cage broken refer fig.4 & 5. Similarly, in 2018 Stand no 15-gearbox failed during service with same phenomenon of input shaft NDE bearing damaged & gear teeth damaged refer figure 6. In all the cases the gearbox was failed very prematurely within 2 years. Normally for Mill duty gearboxes ideal TBM is 5 years or more in some cases.



Fig.4 Failed gearbox of stand no 16 Fig.5 Broken cage bar of input shaft bearing of stand no 16-gearbox



Fig.6 Failed gearbox of stand no 15



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#### A. Metallurgical Analysis of Bearings

In all failure cases of mill stand gearboxes, failed bearings and it components metallurgical analysis was done in Sc Services Lab. No gross material abnormality with respect to chemistry, hardness and microstructure was observed in the bearing elements.

#### B. Current Load Analysis on mill Stand Gearboxes

IBA Data was analyzed for all stands during the last one year. The load trend from 01.09.2019 to 22.09.2020 for stand no 1 is plotted in graph trend & given below in figure 7. From below data analysis, it was found that in past one year, there are 35,862 nos. of billet rolled which had peak toque value more than 100% rated input torque of gearbox which constitute around 9% of total billet rolled in a year (i.e. total 4.6 lakh billets) whereas for rest 91% billets peak torque was found with in rated capacity of gearbox. As per Mill duty gearbox standard AGMA 6010, only 7 peaks (during start stop i.e. momentarily occasional peaks) are allowed in a day more than rated torque capacity of gearbox. However, there is no standard available for operation peak load more than 100% and it is addressed through proper selection of gearbox. Taking 7 occasional peaks per day, in one year around 2500 occasional peaks are allowed but in this case of stand no 1, number of billets having peak torque more than rated capacity was large in numbers ie around 35,862 in which 662 no's of billets were critical cases where peak torque had gone more than 125% of rated input torque & 11 nos. were high impact load cases when peak torque was found more than 140% of rated gearbox torque as shown below in table refer figure 8



Fig.7	NBM	Stand	no 1	l load	analysis.	

Blt_temperature_Date	Blt_temperature_avg	Torq_max_1 (KNm)	Percentage of Gearbox <u>Rated torque (%)</u>	Speed_1 (%)	Rolling section
Saturday, July 25, 2020	933.39	3.008	182.30	75.809	12
Sunday, July 26, 2020	964.79	2.454	148.73	68.078	12
Monday, July 27, 2020	947.41	2.446	148.24	66.649	12
Tuesday, July 28, 2020	1016.58	2.436	147.64	72.501	12
Wednesday, July 29, 2020	1015.94	2.415	146.36	67.396	16
Thursday, July 30, 2020	1010.17	2.378	144.12	67.354	16
Friday, July 31, 2020	1026.02	2.371	143.70	67.863	12
Saturday, August 1, 2020	994.16	2.361	143.09	66.309	12
Sunday, August 2, 2020	994.01	2.345	142.12	67.345	16
Monday, August 3, 2020	909.47	2.334	141.45	72.835	16
Tuesday, August 4, 2020	1015.16	2.325	140.91	67.147	16
Wednesday, August 5, 2020	1006.94	2.316	140.36	67.927	12
Thursday, August 6, 2020	1013.34	2.307	139.82	67.361	16
Friday, August 7, 2020	1018.18	2.304	139.64	67.749	16
Saturday, August 8, 2020	1004.49	2.299	139.33	67.77	16
Sunday, August 9, 2020	1014.29	2.298	139.27	67.419	16
Monday, August 10, 2020	1013.88	2.271	137.64	67.323	16
Tuesday, August 11, 2020	1007.56	2.271	137.64	67.914	12

Fig.8 -High impact load cases



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All above 11 nos. critical cases were happened in recent 3 months (i.e between July to Aug'20) and billet temperature was found lower than required range  $1020 \,^{0}$ C to  $1100 \,^{0}$ C which means billet soaking & heating was not done adequately and led to high rolling peak torque. Billet temperature trend for last year also plotted below in bar graph as shown in figure



Fig.9 Billet Temperature Analysis

Around 11% of total billet rolled in past one year was found with average temperature less than required range of  $1020 \, {}^{0}$ C to 1100  ${}^{0}$ C which is closer to peak torque cases of 9% in which torque was found more than 100% of the rated capacity of the gearbox. On 25<sup>th</sup> July at around 11 pm, Maximum peak torque was found 125% of motor Torque ie 3.05 KNm which is equivalent to 180% of gearbox rated torque when the billet temperature found below 950  ${}^{0}$ C (fig.10).

Such high impact torque load is detrimental for bearings cages & caused initiation of cage breakage.



Fig.9 IBA data Analysis on 25th July'20

### C. Service Factor Analysis

From above data analysis, if we consider 2.45 KNm is the peak load on stand no. 1 gearbox (considering 140% loading) and calculated the service factor of gearbox as shown in calculation sheet in figure 11 below. The running service factor for stand no 1 at peak input torque of 2.45 KNm was 1.35 which is not satisfactory because recommended service factor as per AGMA standards for mill duty gearbox on consumed power should be 2 or greater than 2. As per last one-year trend the consumed power at stand no 1 was found maximum 350 Kw (fig.10). So, need to upgrade the gearbox as per consumed power trend. Similar exercise & calculations done for all other mill stand gearboxes of NBM from stand no 1 to 16. Figure 11 showing the calculation sheet of service factors for all NBM stand gearboxes.

Stand	Morgan KW (Morgan	Rated motor	GB rating Design	Consumed Power at
	Spec)	KW	(kW)	Peak load (KW)
1	254	400	258	350





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		Safety factor on absorbed power	1.35	1.60	1.16	0.00	1.33	1.71	1.26	1.61	2.15	2.08	2.01	2.03	0.75	1.81	1.64	2.04	1.52	0.95	1.94	2.09	1.82	1.99	1.84	2.14	1.94	1.84	0.91	1.97	66.0	1.30	1.28				
ulations		Peak Torque (IBA Data)	2.45	2.45	2.96	2.96	3.51	3.51	3.07	3.07	3.72	3.72	3.76	4.30	4.30	3.42	4.45	4.45	4.02	4.02	3.90	3.90	3.67	3.67	6.68	6.68	7.16	7.16	7.16	4.35	4.35	2.41	2.41				
rque Calc		GB Design input torque inc FOS-2	3.31	3.91	3.44		4.66	6.00	3.86	4.93	8.02	7.75	7.55	8.73	3.21	6.21	7.31	9.08	6.11	3.83	7.56	8.16	6.69	7.29	12.29	14.30	13.88	13.18	6.50	II NBM	4.31	3.14	3.08				
Input To		GB Design input torque	1.65	1.96	1.72	2.56	2.33	2.40	1.93	2.47	4.01	3.10	3.78	4.36	0.00	3.10	3.65	3.63	3.06	1.92	3.78	4.08	3.34	3.64	6.14	7.15	6.94	6.59	0.00	wer for a	3.59	1.57	2.56				
s through	C7	GB KW rating including FOS-2	516	610	536		727	936	602	769	1250	1209	1178	1361	500	896	1140	1416	953	865	1179	1273	1043	1137	1916	2230	2164	2056	1014	sorhed Po	672	489	480				
r Analyis	C6	GB rating Design (kW)	258	305	268	400	363.5	374.478	301	384.55	625	483.701	588.75	680.55		484	570	566.40	476.5	298.8	589.5	636.61	521.5	568.348	958	1114.8	1082	1028		<mark>od on Ahs</mark>			400				
ity Facto	C5	Gear Ratio As per Drg	104.4749	104.4749	75 3	0.01	56 178	56.178			32.233		22.9	3070 11	14.8/80	11.2	60 0	0.02	6 6 204	467C'0	1 2105	CO 1 7.4	3	0.0	00230	60/07		1.9565		heet Base	or how of the		1.5417:1				
tive Safe		Torque (Morgan spec )	2.42	2.42	CV C	74.7	202	10.0	57 5	C 1.7	2 11	-+-0	3.41	FF 6	3.41	3.41	60 6	2.02	0.5 1	4.30	06.1	4.30	C0 C	20.0	50 2	00.7		6.76		lation S			3.07				
ar Box Effec	C4	Calculated Rated Motor Torque based on Rated Power and base Speed(C2/2*PI *C3/60)	2.56	2.56	3 E G	00.7	086	60.7	956	00.7	2 24	170	3.21	166	3.41	3.21	0 E D	80.0	101	4.04	101	4.0.4	2 60	80.0	89.9	0.93		6.50		Factor Calci			2.56				
rive Ge		Motor Base speed	1490	1490	1400	001	0071	1490	1490	001	1400	1430	1490	0077	1490	1490	0077	1430	1400	1430	0077	1490	0077	1430	1 100	1430		1490		Prvice			1490				
M Mill C	C3	Motor Speed	1400/2000	1400/2000	0006/0011	00070041	1100/2000	0007/0041	0006/0071	00070041	0006/0001	1400/2000	1400/2000	0006/0011	0007/0041	1400/2000	0006/001 1	1400/2000	0006/0001	1400/2000	0006/001 1	0007/0041	0000/001 1		0000/001 1			1400/2000		Fig.11-	0		1400/2000				
NB	C2	Rated motor KW	400	400	007	001	150	400	400	001	200	nne	500	200	500		660	000	003	000	063	000	000	nac	0000	0001		1014			560		400				
		OEM KW (OEM Spec)	355	355	366		150	4:00	400	00t	200	nne	500	200	500		500		500		200	nac	063	020	063	000	000	000	1001	6601		066			560		450
		Spare GB details	1A	18	2A	2B	ЗA	3C	4A	4B	5A & 5B	2C	<b>6A</b> & 6B	7A & 7B	7C	8A & 8B	9A & 9B	90 06	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	14C	15A (EMG)	15B.15C, <b>15</b> D	16A (EMG)	16B, <b>16C</b> ,16 D				
		Stand	٢		c	4	c	0	Ā	t	u	n	9	~	'	8	c	ת	0	2	7	-	ç	12		2		14			15		16				



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#### III. RESULTS & DISCUSSION

From above service factor calculation sheet (shown in fig.11) for all mill stand gearbox 1 to 16 of NBM, it is concluded that the roughing stand gearbox from 1 to 4 and finishing stand gearbox 15 & 16 were found to have critical lower service factor (lower than 1.5) than required 2 as per mill duty gearbox AGMA standard based on actual absorbed power.

Further intermediate mill stand gearbox like 8, 9 & 10 were found with marginal lower service factor than recommended.

#### IV. CONCLUSION

From all above analysis, it is concluded that New Bar Mill stand gearbox no 1,2,3,4, 15 and 16 has very low service factor on consumed power trend as on date which causing the premature failure in gearbox input shaft assembly within 1 to 2 years.

Further due to high number of billets in which peak torque load was found more than rated input torque of gearbox causing the cage failure of input shaft bearing and, in few cases, peak load may cross more than critical 140% of gearbox rated torque which aggravated the cage breakage due to high impact load.

#### V. RECOMMENDATION

To prevent premature failure of New bar mill stand gearboxes and to improve reliability, following actions should be employed.

- For all mill stand gearboxes high torque alarm to be given on gear box nominal input torque rating (for example Stand#1 nominal Torque load is 1.65 KNm). If it goes beyond the nominal input torque for 5 seconds, then it will trigger an alarm and auto stoppage of subsequent billet discharge from furnace for 3 minutes.
- Current logic of stand 1 trip at 90 % (2.5KNm) motor torque in case of cold billet to be changed to 78 % (1.91 KNm). Trip command to be generated if stand 1 cross 78 % of motor torque (which is 120% of gearbox nominal torque value) for one second. Tripping of stand#1 in case of cold billet having low temperature will not allow the cold billet to move further in other mill stands thus avoid overloading.
- Gearbox to be procured as per upgraded specification and put in service. Design power rating of the upgraded gearbox should include service factor 2 (or greater than 2) on nominal consumed power rating.

#### VI. ACKNOWLEDGMENT

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