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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 (150×150) mm^2 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.

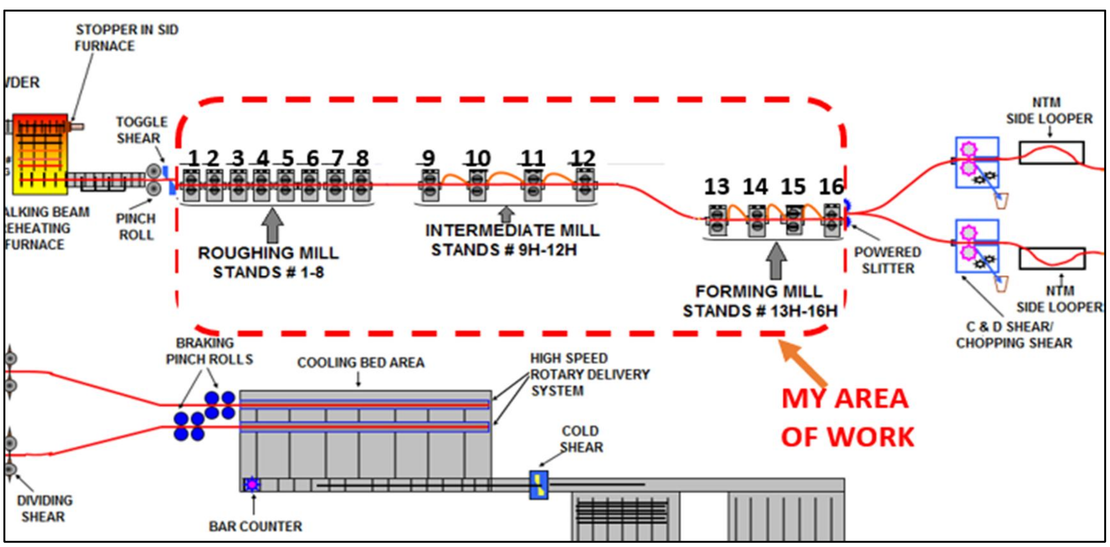
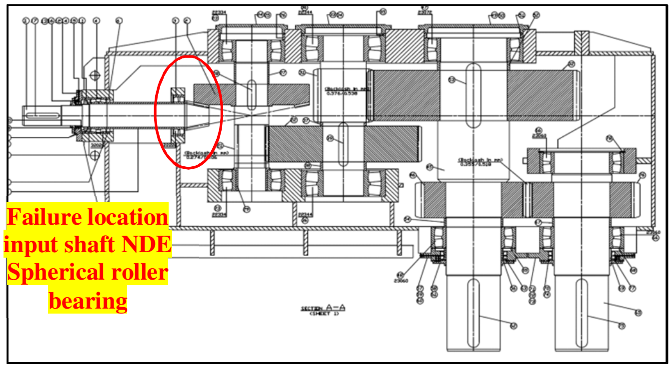


Fig.1 OVERVIEW OF MILL STAND GEARBOXES

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.

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.



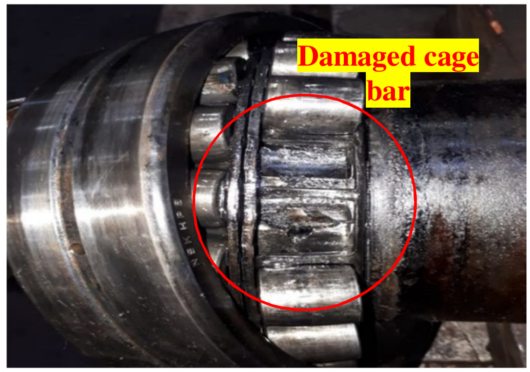


Fig.2 GA drawing of NBM stand 1 Gearbox   Fig.3 Failed Bearing of Stand no 1 gearbox.

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.

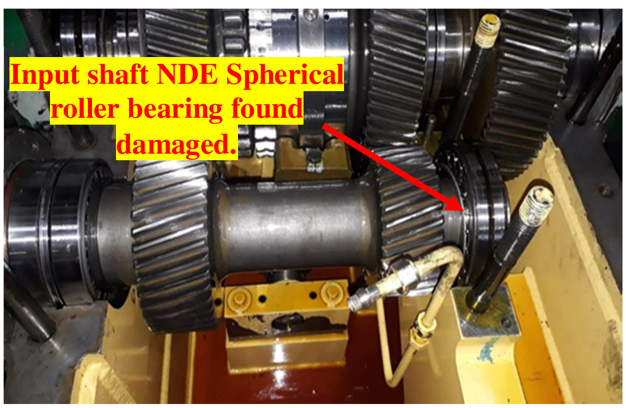


Fig.4 Failed gearbox of stand no 16   Fig.5 Broken cage bar of input shaft bearing of stand no 16-gearbox

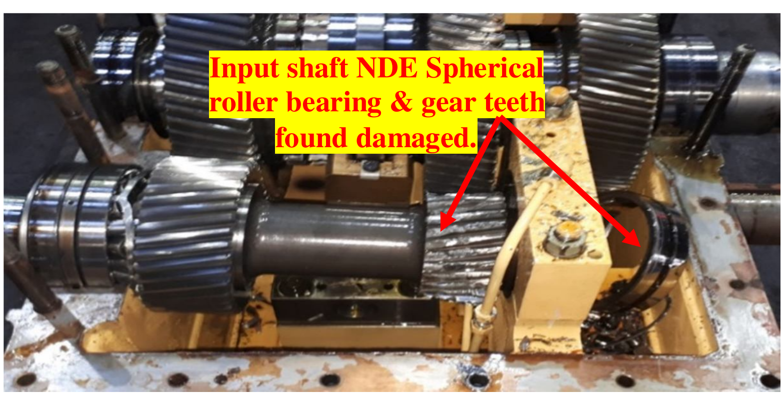


Fig.6 Failed gearbox of stand no 15

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

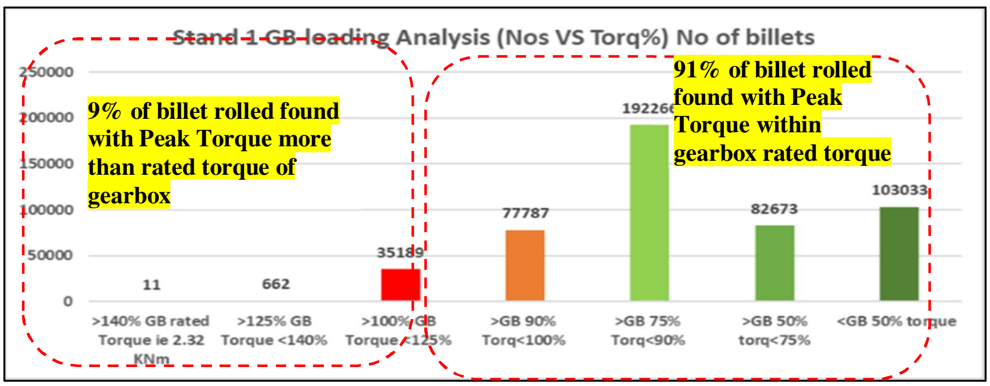


Fig.7 NBM Stand no 1 load analysis.

Blt_temperature_Date	Blt_temperature_avg	Torq_max_1 (KNm)	Percentage of Gearbox Rated torque (%)	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

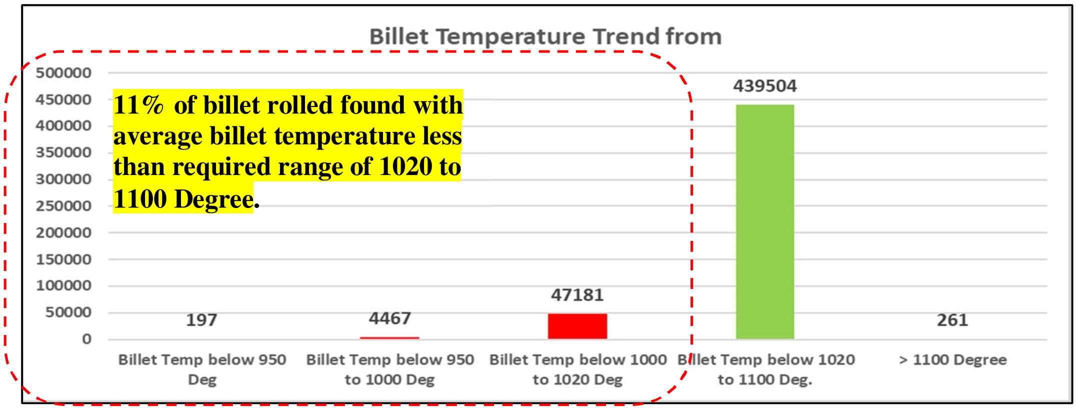

Fig.9 Billet Temperature Analysis

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 25th 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.

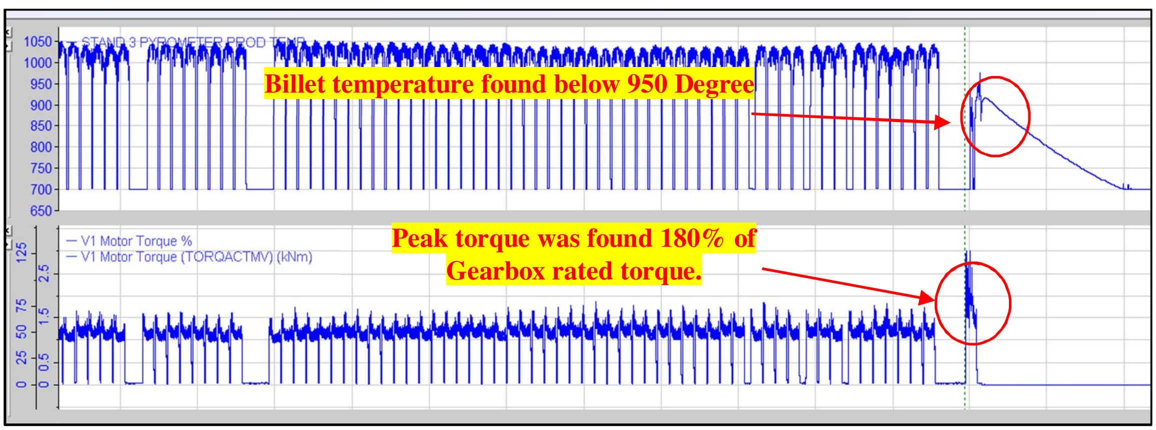

Fig.9 IBA data Analysis on 25th July'20

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

Fig.10

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NBM Mill Drive Gear Box Effective Safety Factor Analyis through Input Torque Calculations														
			C2	C3		C4		C5	C6	C7				
Stand	Spare GB details	OEM KW (OEM Spec)	Rated motor KW	Motor Speed	Motor Base speed	Calculated Rated Motor Torque based on Rated Power and base Speed(C2/(2*PI *C3/60)	Torque (Morgan spec)	Gear Ratio As per Drg	GB rating Design (kW)	GB KW rating including FOS-2	GB Design input torque	GB Design input torque inc FOS-2	Peak Torque (IBA Data)	Safety factor on absorbed power
1	1A	355	400	1400/2000	1490	2.56	2.42	104.4749	258	516	1.65	3.31	2.45	1.35
	1B	355	400	1400/2000	1490	2.56	2.42	104.4749	305	610	1.96	3.91	2.45	1.60
2	2A	355	400	1400/2000	1490	2.56	2.42	75.3	268	536	1.72	3.44	2.96	1.16
	2B								400		2.56		2.96	0.00
3	3A	450	450	1400/2000	1490	2.89	3.07	56.178	363.5	727	2.33	4.66	3.51	1.33
	3C								374.478	936	2.40	6.00	3.51	1.71
4	4A	400	400	1400/2000	1490	2.56	2.73	41.12	301	602	1.93	3.86	3.07	1.26
	4B								384.55	769	2.47	4.93	3.07	1.61
5	5A & 5B	500	500	1400/2000	1490	3.21	3.41	32.233	625	1250	4.01	8.02	3.72	2.15
	5C								483.701	1209	3.10	7.75	3.72	2.08
6	**6A** & 6B	500	500	1400/2000	1490	3.21	3.41	22.9	588.75	1178	3.78	7.55	3.76	2.01
7	7A & 7B	500	500	1400/2000	1490	3.21	3.41	14.8786	680.55	1361	4.36	8.73	4.30	2.03
	7C									500	0.00	3.21	4.30	0.75
8	8A & 8B	500	500	1400/2000	1490	3.21	3.41	11.2	484	968	3.10	6.21	3.42	1.81
9	9A & 9B	560	560	1400/2000	1490	3.59	3.82	8.82	570	1140	3.65	7.31	4.45	1.64
	9C								566.40	1416	3.63	9.08	4.45	2.04
10	10A	630	630	1400/2000	1490	4.04	4.30	6.5294	476.5	953	3.06	6.11	4.02	1.52
	10B								298.8	598	1.92	3.83	4.02	0.95
11	11A	630	630	1400/2000	1490	4.04	4.30	4.2105	589.5	1179	3.78	7.56	3.90	1.94
	11B								636.61	1273	4.08	8.16	3.90	2.09
12	12A	560	560	1400/2000	1490	3.59	3.82	3.5	521.5	1043	3.34	6.69	3.67	1.82
	12B								568.348	1137	3.64	7.29	3.67	1.99
13	13A	1035	1080	1400/2000	1490	6.93	7.06	2.5789	958	1916	6.14	12.29	6.68	1.84
	13B								1114.8	2230	7.15	14.30	6.68	2.14
14	14A	990	1014	1400/2000	1490	6.50	6.76	1.9565	1082	2164	6.94	13.88	7.16	1.94
	14B								1028	2056	6.59	13.18	7.16	1.84
	14C									1014	0.00	6.50	7.16	0.91
15	15A (EMG)	560	560	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.35	1.97
	15B.15C,**15 D**								560	672	3.59	4.31	4.35	0.99
16	16A (EMG)	450	400	1400/2000	1490	2.56	3.07		244.5	489	1.57	3.14	2.41	1.30
	16B,**16C**,16 D							1.5417:1	400	480	2.56	3.08	2.41	1.28

Fig.11- Service Factor Calculation Sheet Based on Absorbed Power for all NBM Stand Gearboxes 1 to 16.

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

M/s Elecon, M/s Shanti gearboxes OEM for drawings & technical Supports.

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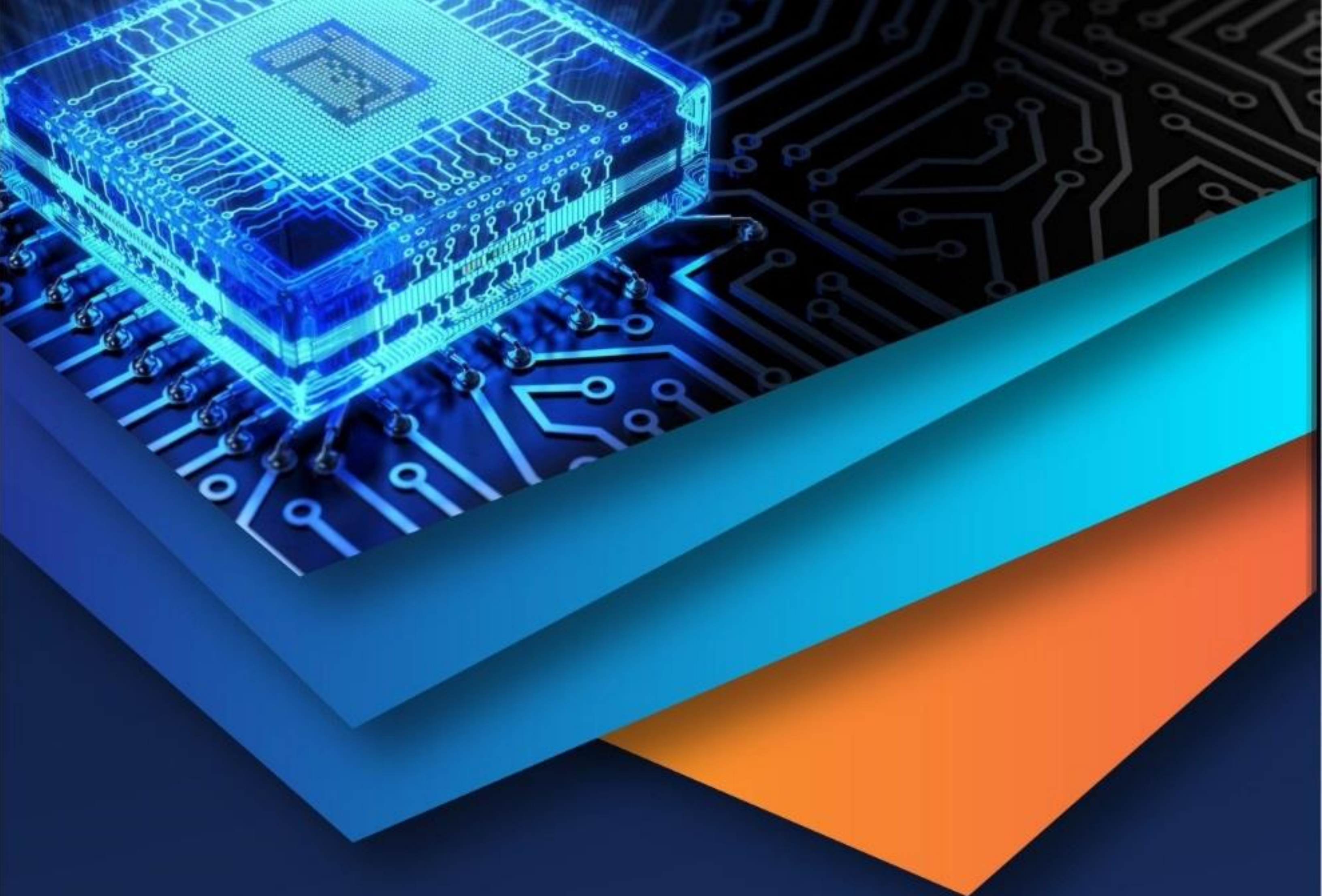

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