

Analyzing Operating Behavior of Hot Mill Table Roll Drives using Statistical Methods for Current Values

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Abstract. The article briefly describes failures of table rolls in Hot Rolling Mill 2000, PAO Severstal, and provides research results obtained by applying statistical methods. The statistical analysis showed a possibility of detecting deviations in roll behavior based on electric drive current changes, which cause failures. The statistical data analysis was employed to define roll critical behavior, which is to be checked using additional data. For this purpose, the research will be continued, roll operating behavior will be studied during the entire lifetime with due regard for deviations detected, comprehensive statistical analysis will be carried out, influence of rolling mill practices and roll failure predictability will be assessed.

1 Introduction

Maintaining process equipment in a good operating condition is among top priorities of any company. Scheduled maintenance and repair cannot always ensure trouble free operation. Steelmaking facilities (blast furnaces, BOFs, continuous casting machines, hot and cold mills etc.) are sophisticated engineering systems, therefore it is quite complicated to identify and consider all factors influencing failures. Different approaches are employed for failure cause analysis and maintaining fault free operation of equipment. As production process is rather complex, steelmaking facilities are highly automated. Automatic Process Control System (APCS) records data bulk, which can be used for research, search for dependencies, identification of factors causing failures. Therefore, statistical methods can be widely used for this purpose [1].

The article briefly describes failures of table rolls in Hot Rolling Mill 2000, PAO Severstal, and provides results of statistical investigation.

Most common roll failure is a seizure of mechanical components, which has a negative impact on neighboring rolls operation and increases probability of their failure. The increase in number of rolls to be repaired causes longer roll change time and lower mill productivity. Failures of run out table rolls can cause scratches and burrs on the strip.

As literature review shows, different approaches and methods [2–15] can be employed for diagnostics of electric drive mechanical components and failure cause analysis, including statistical analysis for changes in current and speed values. It should be noted that relatively few works [12–15] have been devoted to failure causes analysis of table rolls in hot strip mills. Besides, the works contain approaches and part of research results, and demonstrate how difficult and urgent it is to find solutions for roll failures.



2. Research and results

The research will consist of a few stages.

The first stage included data analysis for changed values of electric drive current and linear speed of rotating rolls and identification of deviations in rolls behavior related to the failure causes. The results of the first stage are presented in this article. It should be mentioned that a small number of rolls were used for analysis due to massive records per each roll, which is more than 4 million during 2-3 weeks of roll operation.

The second stage is to include collecting additional data regarding roll behavior deviations detected in the first stage during entire life and conducting analysis to prove their impact on failures.

The third stage is to include carrying out a statistical analysis of data bulk applying modern methods, assessing rolling practices impact on failures and developing a prediction model.

The fourth stage, which is the last one, is to include implementing software algorithms for table rolls diagnostics after maintenance and during operation.

The first stage included collecting data for statistical analysis regarding changed values of electric drive current and linear speed of rotating table rolls during relatively short periods of 3–4 week before failure. Rolls for analysis were selected by three with a faulty one in the middle. This selection pattern allows to compare operating conditions of the faulty roll with neighboring ones. Finally, 5 series, each including 3 rolls, were selected for analysis. For analysis, data was translated into more convenient form; statistical values were calculated: mean value and standard deviation, minimum and maximum, number of values exceeding 100 A and number of values of 200 A. Those values were calculated for one hour of roll operation. Data, recorded every 0.5 s, was reviewed for a detailed analysis of roll behavior. Comparative analysis of mean values and standard deviations was carried out for certain operating modes, when applicable.

The study included review of bar charts, correlation fields, time profiles of current and speed. Figures 1 and 2 show time profiles of current and linear speed. As Figure 1 shows, 400 operating hours of roll 22 saw numerous current peaks demonstrating load for electromechanical system. More detailed analysis of roll 22 operation revealed some patterns in current changes (Figure 2) and the fact that its operating behavior has lowest deviations against normal ones. Evaluation of roll 22 operating behavior confirmed that this roll could be used as a reference for comparison with operating behavior of other rolls and search for deviations.

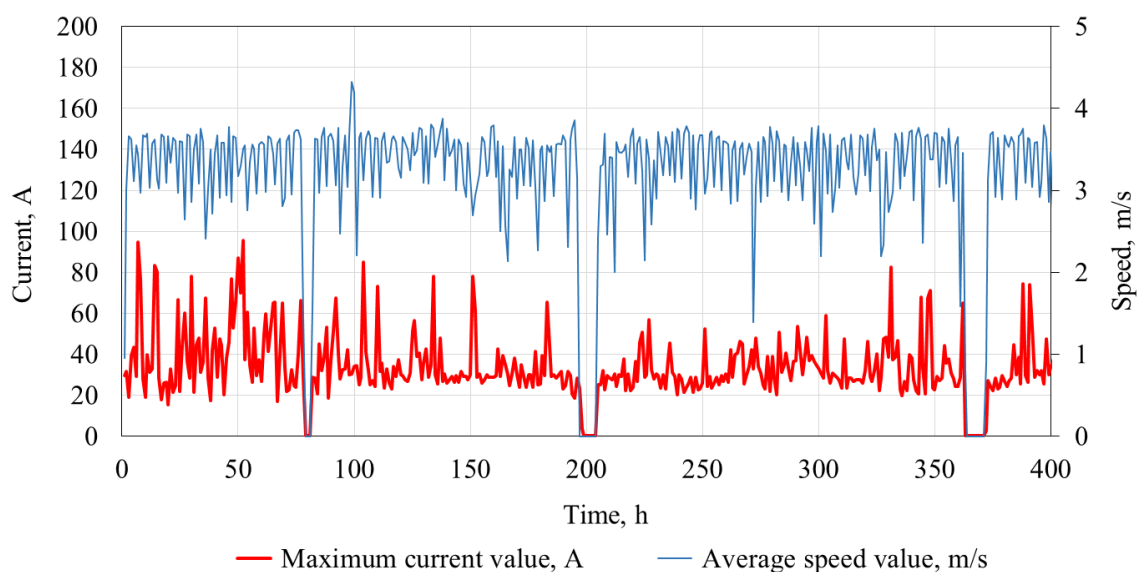


Figure 1. Change in electric drive current and roll 22 linear speed for 400 hours.

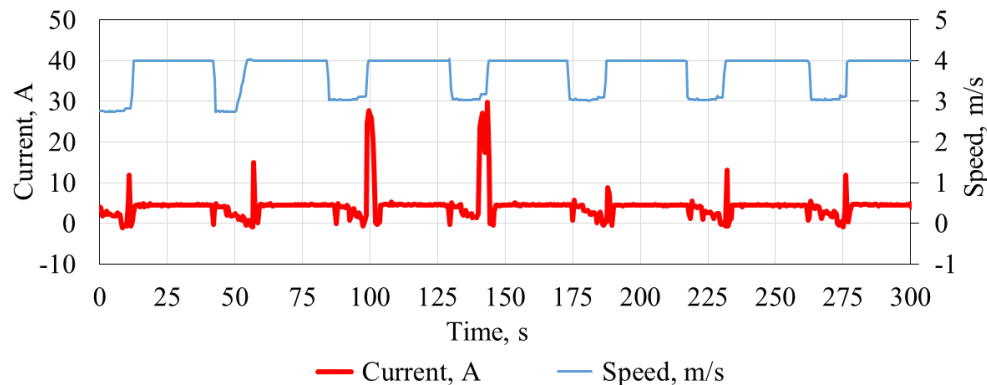


Figure 2. Change in roll 22 electric drive current for 300 s.

Analysis of other rolls operating behavior in terms of change in current showed different deviations for mean values, range, number of peak values exceeding 100 A and others. It should be noted, that among the most common deviations in roll behavior are peak values – current spikes from 100 to 200 A, which increase failure probability. Current spikes are seen in dynamic modes (slowdown) when load changes. Dynamic shocks in electromechanical system of the drive have a negative impact on its technical condition. Figure 3 shows roll 23 having numerous peak values. Roll 23 seized a few times within 400 hours of operation – during hour 175, 310 and 330.

Data was compiled in Table 1 for comparative analysis of roll operating behavior. As Table 1 shows all faulty rolls except roll 14 operated under conditions with peak values of 200 A.

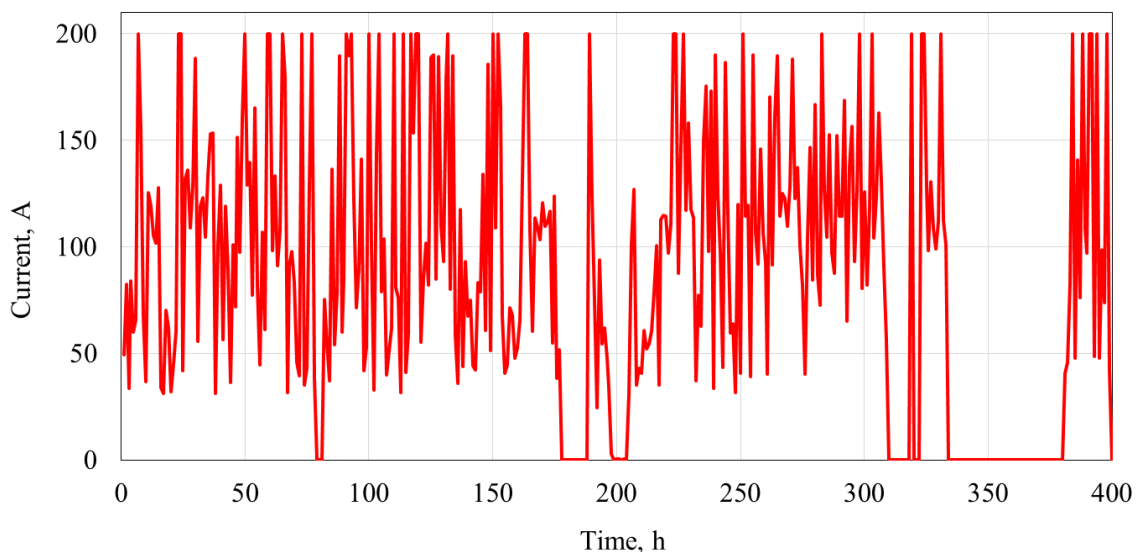


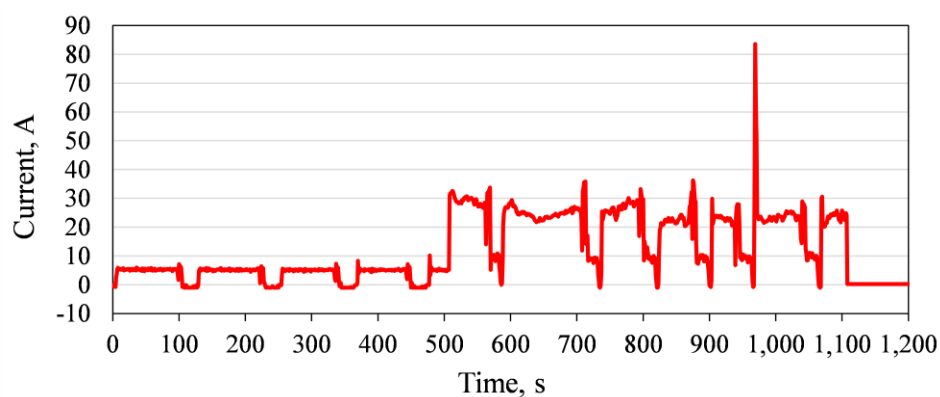
Figure 3. Change in current (highest values) of roll 23 electric drive for 400 hours.

Figure 4 shows time profile of current change for electric drive of roll 14, which failed due to the seizure of a bearing. As Figure 4 shows, average current values increased up to 25 A in second 506 (including increase in values range), then seizure occurred in second 1,108. At the same time, there were no obvious deviations in operating conditions of roll 14 before increase of the average value up to 25 A. Besides, there were no changes in operating conditions of neighboring rolls.

Table 1. Change in current of rolls' electric drive motors.

Series No.	Roll No.	Percent of rolls operating conditions, %					Note
		200 A	from 100 to 200 A	from 50 to 100 A	from 20 to 50 A	less than 20 A	
1	22	0.0000	0.0002	0.03	0.66	99.31	Operating
	23	0.0202	0.3874	0.64	8.49	90.47	Seized
	1	0.0000	0.0010	0.08	3.95	95.96	Operating
2	20	0.0006	0.0241	0.53	4.99	94.45	Operating
	21	0.0634	0.0450	0.57	16.90	82.41	Seized
	22	0.0005	0.0188	0.24	3.10	96.65	Operating
3	9	0.0031	0.0025	0.03	0.29	99.67	Operating
	10	0.0111	0.0107	0.43	35.95	63.60	Seized
	11	0.0049	0.0644	0.33	3.04	96.55	Operating
4	13	0.0000	0.0190	0.20	0.54	99.24	Operating
	14	0.0000	0.0048	0.21	3.59	96.19	Seized
	15	0.0000	0.0034	0.14	1.22	98.65	Operating
5	15	0.0000	0.0014	0.19	4.04	95.77	Operating
	16	0.0012	0.0045	0.38	4.15	95.46	Seized
	17	0.0000	0.0012	0.33	7.44	92.23	Operating

As correlation analysis showed, there was only a slight correlation in operating conditions of rolls neighboring the faulty one (the coefficient of determination is less than 0.2), that is a sudden change in electric drive current of one roll does not always cause current spikes of the neighboring roll. When no deviations occur, the coefficient of determination can reach 0.85. It should be mentioned, that these changes in roll (14) operating conditions indicate that not all failures can be detected beforehand. Table 1 shows that at the time of the study some of active rolls had current spikes up to 200 A, for instance, roll 11 (series 3). Therefore, data collection should be continued for checking an impact of detected deviations on failures. The second stage is to include collecting data regarding deviations of each roll during its entire life and performing analysis based on cumulative damage theory [11, 12].

**Figure 4.** Change in current of roll 14 electric drive for 1,200 seconds before seizure.

3. Conclusion

In the first stage of the study statistical analysis was conducted for change in current of electric drives for intermediate table rolls in hot strip mill. It showed a detectability of deviations in roll operating conditions, which cause failures. Roll critical operating conditions were defined based on the statistical analysis results. In future collection of data on deviations detected will be continued and rolls operating conditions will be studied during their entire life.

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