Chapter 123
Large Data and AI Analysis Based Online Diagnosis System Application of Steel Ladle Slewing Bearing

Wei Hu, Fengshou Gu, and Shiqi Chen

Abstract Setting the default diagnosis and residual longevity of steel ladle turret bearing as the research subject, this article developed a large data and fusion of data mining with expert system based AI default diagnosis system, which has been successfully applicated in the default diagnosis of steel ladle turret bearing of a steel, saving tremendous time for steel mill's decisive equipment maintenance by precisely predict the residual longevity of the equipment.

123.1 Introduction

The footstone of productional benefit of metallurgical Industry is the regular operation of the key equipment. The default of key equipment will cause the entire production line to stop, interrupt the production arrangement and be highly disturbing for the regular production and economical benefit of the company.

The steel ladle turret is the key equipment of continuous caster. It is functional by connecting the previous and afterward working procedure and is usually located between the molten steel receiving span and casting span column [1]. This equipment contains certain characteristics as followed:

(1) Categorized as large-scale low-speed equipment;
(2) Operative environment is relatively harsh, large impacting load;
(3) Usually no storing spare replacement due to the high-cost of the equipment;
(4) Long operating time, low halting time.

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In the composing parts of steel ladle turret, steel ladle of slewing bearing is the key composing part that keeps the steel ladle turret works stably and high-efficiently. In order to guarantee the regular operation of the slewing bearing, factory will require available on-site worker to manipulate a high-density check toward the bearing. However, due to the harsh on-site condition, the high difficulty of on-site checking, not only the working stiffness of worker has been escalated, but also the worker's life and safety are also in danger. For now, there is a lack of efficient fault detecting method of this bearing. Also, after the occurrence of the default, default signal is very unclear which makes the detection of the bearing's default in difficulty. By a high possibility of double-damage of equipment, the company has to carry an extra economic burden with the increasing fixing cost.

Thereafter, the condition detecting and default diagnosis of the steel ladle turret slewing bearing is not only the demand of metallurgical Industry to guarantee the regular operation of continuous casting procedure for the regular production. It will also be beneficial in the respect to prompt the revolution of equipment management system.

123.2 The Characteristics of the Operation of Steel Ladle Turret and It's Difficulty of Default Diagnosis

Located between the molten steel receiving span and casting span column steel ladle turret carries two ladles on its rotating arm which can conduct a rapid yet smooth Trans-transport on ladles, actualizing the fast renewal of "full ladle" and "empty ladle". In addition, it achieves the continuity of casting procedure by the incorporation with steel ladle and crystallizer. More detail equipment structure is seen in article [2].

The technical difficult points for steel ladle turret bearing's default diagnosis:

(1) Causing by the low rotating speed, impacting energy released by damage of bearing is very low; also, the equipment is highly disturbed by inferior force, noises can easily cover the default characteristic of bearing damage; As the result, normal bearing diagnosis techniques, such as, time domain analysis, frequency domain analysis, Envelope demodulation spectrum and etc. can't effectively detect the damage characteristic of bearing.
(2) Bearing force is complex it endures axial force, radial force and overturning moment simultaneously.
(3) While the equipment is operating, due to the harshness of on-site condition, faculties are not allowed to enter; in addition, a single off-line detecting can't value the mechanical state of the equipment efficiently. As the result, the data quantity is not efficient for decision making of the equipment's mechanical state.
(4) Detecting the default of the equipment is not the only goal. Predicting the bearing's residual longevity is also necessary for the guiding the fixing

orientation, exerting the maximum value of the equipment, gaining time for the preparation of replacing spare parts.

(5) The accuracy of diagnosis analysis can't be assured even the diagnosis faculties are highly professional and experienced for having the most accurate vibration analysis.

123.3 Design of a Big Data and AI Basing Default Diagnosis System for Steel Ladle Turret

For better fulfilling the need of precise default locating and precise predicting of residual longevity of steel ladle turret bearing, our company designed a big data and AI basing default diagnosis system for steel ladle turret. The structure of the system is showed as Fig. 123.1.

Figure 123.1 is the big data and AI basing default diagnosis system of steel ladle turret. It includes four layers as fallow:

The first layer is Data collecting layer: It collects data such as, vibration, production process, angle, rotating speed, operating time and etc.; In between, data of vibration includes three part: acceleration, vibrating speed and vibrating replacement; production process involves electric current, voltage, molten steel level and etc.; angle is the leaning angle of the steel ladle turret itself; transducer will then send the data to the data collecting station which is an important intermediate equipment;

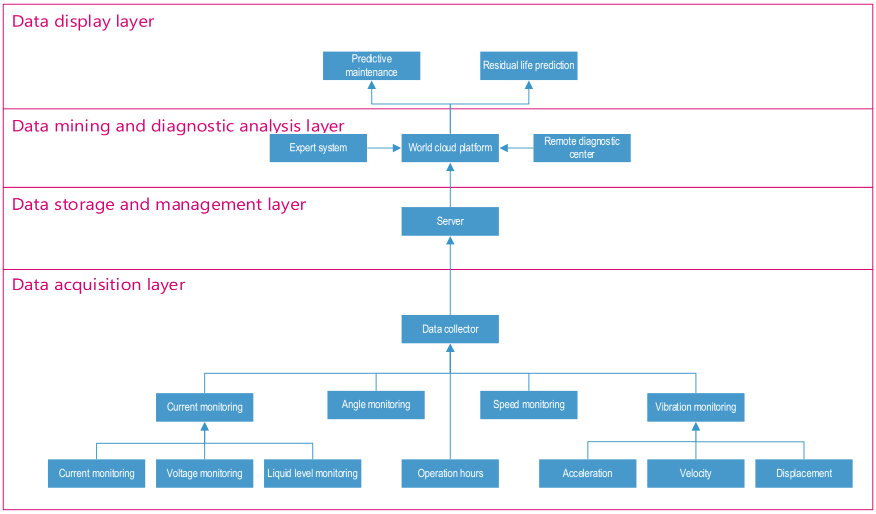


Fig. 123.1 The big data and AI basing default diagnosis system for steel ladle turret

The second layer is Data storage and management layer: It stores the data sent by data collecting station, providing the necessary I/O, managing the Data collecting layer and the categories of data collected.

The third layer is Data mining and diagnosis analysis l: It predicts and analyzes the equipment's constant data from the Data collecting layer; accurately determining the operating state of the equipment in the fallowing two stage:

(1) Data mining: this part integrate 18 default diagnosis algorithm [3] ,including vibration tendency analysis, time domain waveform, frequency spectrum analysis, long waveform tendency analysis, long waveform, Sampling Trend Analysis, Speed, Waveform Processing, Envelope Demodulation, Cross Phase, Frequency Trend, Technological Trend and so on algorithm; coalescing with algorithm of neural network and data mining cored AI intelligent diagnosis algorithm [4, 5], constantly exploring data value and algorithm of improving diagnosis.
(2) Diagnostic analysis includes remote online diagnostic analysis, expert system and World cloud platform. Based on the diagnostic analysis conclusions, it provides professional artificial intelligence diagnosis and analysis, evaluates and improves equipment operation status and maintenance strategy, and extends equipment life. Accurately predict the residual life of the main bearing.

The fourth layer is the data display layer: it mainly provides diagnostic application services to customers, and provides services for various application clients such as mobile APP, WEB client and desktop client, and displays the diagnosis results to customers in all directions. Confirmation of the diagnosis result are certified terminally by clients.

With a big data base of operating parameters of various equipment and a platform, based on a variety of fault diagnosis algorithms, expert systems and data mining algorithms based artificial intelligence fault diagnosis systems, the system forms a customer-oriented closed-loop system, which use practical performance as a test of accuracy, to continuously optimize the system.

123.4 Application Practice

The slewing bearing on the ladle turret of a steelmaking company of Shandong Lai Gang is a three-row roller slewing bearing. Rotate for about half a minute to stop. After pouring for 45 min, it continues to rotate. Half a minute of rotation later, it cast again. The rotation speed is 1.5 min/r, and the lubricating grease is lithium molybdenum disulfide. The device has been running for 8 years.

According to the condition of the outer housing of the slewing bearing, the transducers are arranged at the positions shown in Fig. 123.2, distributed around the slewing bearing, each group of transducers is installed at 90° apart; each marked position is placed with a corresponding transducer, which is installed on the important position of the bearing's loading portion.

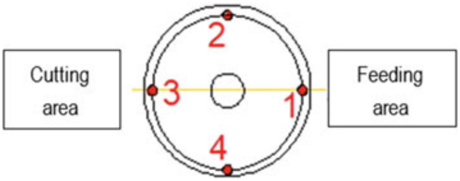


Fig. 123.2 The position of online monitoring transducer system

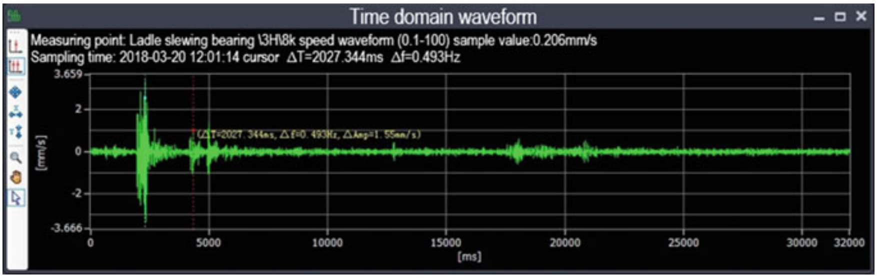


Fig. 123.3 3H measuring point A-direction vibration trend chart

The intelligent system was installed on February 15, 2018, and an online monitoring system was also installed due to the length of the construction period. Through continuous online monitoring, it is found that the time-domain waveform vibration shock of the slewing bearing is obvious, and the sampling value trend (acquisition of a set of data in 5 min) has obvious high amplitude phenomenon, without any regularity, as shown in Figs. 123.3 and 123.4, respectively. However, after analysis of the conventional bearing defect frequency analysis tool, it is not possible to determine whether the bearing is faulty.

Through continuous acquisition and monitoring of one month's data, a large number of real-time data of equipment operation were obtained. With the support of the expert system, the load distribution and variation of the main bearing (support bearing) were calculated and analyzed. After the self-learning of the neural network analysis algorithm and the online intelligent diagnosis algorithm, the fault characteristic index curve of the main bearing was found, as shown in Fig. 123.5 below.

The following conclusion can be drawn from Fig. 123.5:

(a) The impact signals at the two positions 1 and 3 are the strongest, indicating that the damage at these two locations is the most serious. It can be seen from Table 123.1 that the H direction (radial direction) of each measuring point is significantly higher than the A direction (axial direction), and the judgment is related to the overturning moment;
(b) The damaged parts are mainly the two parts of the bearings 1 and 3, and the raceways of the 1st and 3rd parts are severely worn;
(c) Residual life prediction is 4 weeks.

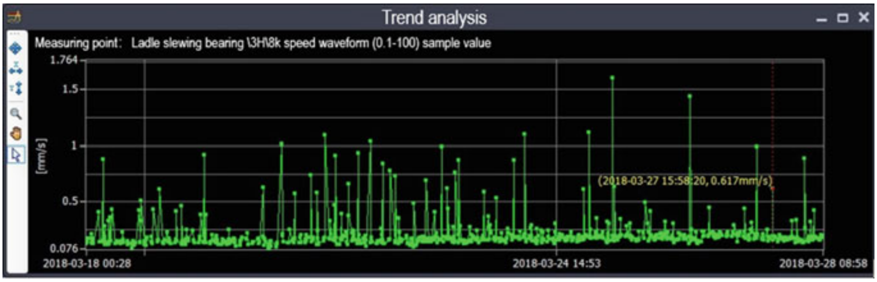
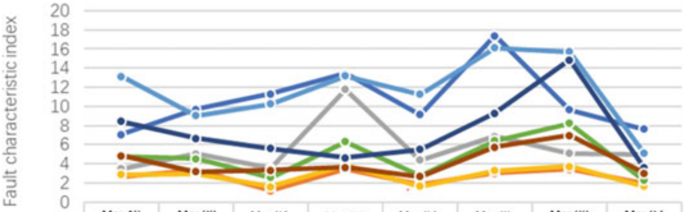


Fig. 123.4 3H measuring point A-direction vibration trend chart



	Mar 19	Mar 20	Mar 21	Mar 23	Mar 24	Mar 25	Mar 26	Mar 27
1H	7.08	9.721	11.337	13.45	9.154	17.409	9.623	7.6
1A	2.678	3.326	1.213	3.422	1.872	3	3.432	1.919
2H	3.488	5.068	3.525	11.793	4.391	6.859	5.076	4.995
2A	2.877	2.994	1.627	3.839	1.659	3.275	3.732	1.671
3H	13.14	9.019	10.248	13.174	11.289	16.117	15.727	5.114
3A	4.777	4.544	2.573	6.298	2.765	6.385	8.209	2.243
4H	8.431	6.675	5.609	4.627	5.482	9.27	14.852	3.568
4A	4.854	3.161	3.342	3.616	2.645	5.73	6.977	3.013

Fig. 123.5 Fault characteristic index curve of each measuring point of slewing bearing

In order to verify the system's judgment on the accuracy of bearing damage and residual life prediction, the following two aspects were verified:

(1) Evaluation of bearing online wear status

In order to verify the accuracy of the judgment of the damaged part of the bearing, an online oil analysis method was used for verification. Since the sampling of the oil has a very important influence on the detection result, if the sampling position is not good, the actual situation cannot be truly reflected, which may cause a wrong judgment on the degree of damage of the slewing bearing, and the goal of predicting the verification system's accuracy cannot be obtained. By analyzing the structure and stress state of the equipment, it is determined to obtain the oil sample from the lowermost seal of the loading section's upper bearing of zone 1 and the lowermost seal of the side bearing of zone 3, the upper seal of the bearing of the 2 (or 4) zone and the analysis results are shown in Fig. 123.6.

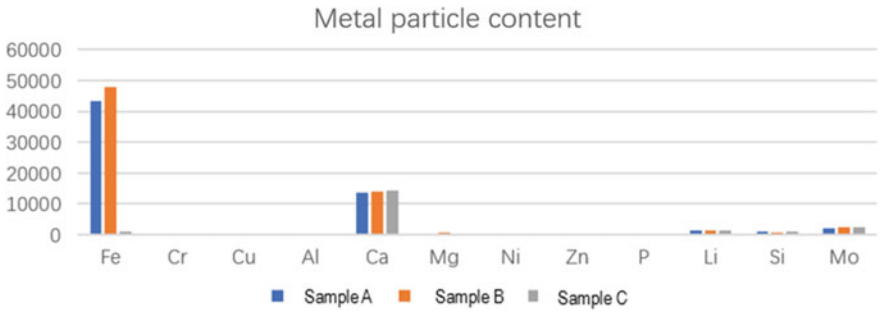


Fig. 123.6 Analysis results of elemental analysis of oil samples in areas 1 and 2

Fig. 123.7 Slewing bearing dissembled

Observing the Fig. 123.6, the following conclusion can be drawn:

(a) the bearing has been severely damaged;
(b) The grease contains a large amount of wear and tear, and the iron content in the grease leaking from the lower part of the bearing is about 8 times higher than the normal alarm limit;

Note: The test standard for elemental analysis is NB/SH/T0864-2013.

The results of online wear monitoring verify the fault detecting accuracy of the artificial intelligence fault diagnosis system for the fault area of the slewing bearing.

(2) On-site disassemble verification

On April 7th, the slewing bearing was stuck and could not continue to operate. The customer disassembled the ladle turret and replaced the new bearing. The photo of the bearing disassembled is shown in Fig. 123.7, and the vibration data before and after the replacement of the bearing is shown in Fig. 123.8.

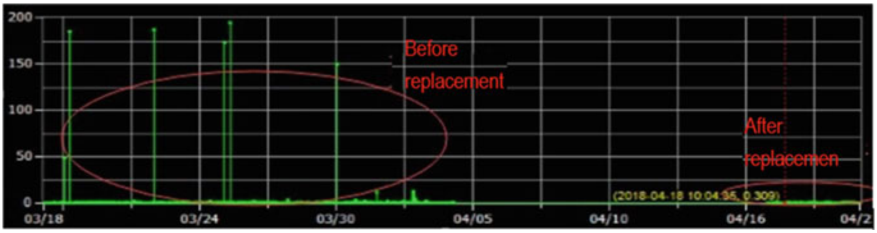


Fig. 123.8 The vibration data before and after the replacement of the bearing

After dismantling, it was found that the rolling bearing of the slewing bearing was severely peeled off, and the bearing inner ring raceway was severely peeled off. The peeling of the bearing area of the bearing 1 and 3 was more serious than that of the 2 and 4 areas, which was consistent with the system prediction and judgment, and verified the residual life predicting accuracy.

On April 10, the equipment was restarted after the bearing was replaced. The fault characteristic index of each bearing point was re-acquired through the online monitoring system. The fault characteristic index of position 2 is shown in Fig. 123.8.

Observe Fig. 123.8. Before and after the replacement, the amplitude of the index changes very obviously. Before the replacement, the amplitude is very high, and the amplitude after replacement is very low. On the other hand, it is verified that the index can accurately determine the damage degree of the main bearing.

Since the accuracy of the system judgment has been verified and approved by the customer's practice, the mill has installed the system on other ladle turrets to monitor the operation of the equipment and provide important data support for predictive maintenance of the equipment.

123.5 Conclusion

In this paper, the support of ladle turret is taken as the research object, and the difficulty of fault diagnosis is analyzed. Based on this, a big data and artificial based intelligence analysis fault diagnosis system for ladle slewing bearing has been designed. The system includes data acquisition layer and data storage & management, data mining & diagnostic analysis layer and data display layer, forming a closed-loop operation from monitoring to maintenance, and successfully applied to a Steel company of Shandong Laigang. Through the application of the system, the failure degree and residual life of the ladle turret support bearing are accurately predicted 30 days in advance, and the spare parts for replacements are prepared for the customer, which gains precious time and avoids the major unplanned downtime caused by the damage of equipment, saving about 10 million yuan of economic benefits for costumer.

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