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A Study on Failure Sign Detection Using Monitoring Data for Air Conditioning Systems of Commuter Trains




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Improved reliability of commuter trains and reduction in maintenance costs can be expected by changing from time-based maintenance (TBM) to condition-based maintenance (CBM). In this study, in order to achieve CBM by a monitoring system, we conducted field tests of an air conditioning system for railway vehicles. Then, we selected appropriate measurement items to apply to the monitoring system.

●Keywords: Air conditioner, Monitoring, Rolling stock, CBM

1 Introduction

In current maintenance of equipment of rolling stock, inspection and repair is done based on travel distance and operating time regardless of deterioration level. If deterioration level and signs of failure can instead be identified by monitoring of items that indicate the condition of equipment, we can expect in the future that timing and details of maintenance required will be determined based on the condition of individual devices of rolling stock.

Up to now, we had carried out bench tests to identify the condition of air conditioners. In those tests, we sought a method where deterioration level and signs of failure could be perceived from data with quantitative indexes and used for maintenance, and we selected items to be monitored.

Consequently, in the study this time, we carried out field tests where trains in operation collected monitoring data of air conditioners for ordinary DC current trains operated in the greater Tokyo area. And we considered a method of analysis for the collected data.

2 Overview of the Study

To identify the condition of air conditioners by monitoring, various condition data expressing that condition is needed. We thus developed a test air conditioner that can obtain data items that the findings of the bench tests proved effective for monitoring, and we installed that air conditioner on trains in operation to collect monitoring data. Using the data collected, we considered an analysis method.

3 Development of a Test Air Conditioner

The test air conditioner developed is based on the air conditioner currently used on conventional lines in the greater Tokyo area (type AU726B, Table 1). The test air conditioner can record monitoring data using sensors that have been added while maintaining current air conditioning functions. It also allows remote collection of the data recorded via WiMAX network. The items to be measured using the added sensors were determined according to past bench test results (Table 2).

Table 1 Specifications of Air Conditioner for Rolling Stock (type AU726B)

Item	Spec
Rolling stock installed to	Series E231 and E233
Rated cooling capacity	58.14 kW
Rated heating capacity	6.0 kW
Circulated air volume	120 m^3/min
Refrigerant	R407C
Compressor	Scroll compressors (2) and Rotary compressors (2)
Outside fan	Axial fans (2)
Inside fan	Multi-blade fan (1)
Outside heat exchanger	2
Inside heat exchanger	2

Table 2 Items Measured in Field Tests

No	Item	No	Item
1	Compressor intake pressure	8	Humidity of air passing through outside heat exchanger
2	Compressor discharge pressure	9	Compressor intake temperature
3	Temperature at return air opening	10	Compressor discharge temperature
4	Humidity at return air opening	11	Outside heat exchanger inlet temperature
5	Temperature of air passing through inside heat exchanger	12	Inside heat exchanger inlet temperature
6	Humidity of air passing through inside heat exchanger	13	Inside heat exchanger outlet temperature
7	Temperature of air passing through outside heat exchanger		

4 Collection of Monitoring Data Using Trains in Operation

We installed the developed test air conditioner on a specific car of a train operated on a conventional line in the greater Tokyo area and conducted tests on the collection of data in commercial operation. The test collection period was about one year from October 2012 to October 2013.

5 Analysis of Collected Data

5.1 Preprocessing of Collected Data

The air conditioners have seven output levels, and it is known that data output results differ according to those levels. Thus, in order to make conditions uniform, we selected specified levels to be used for analysis. Furthermore, we examined preprocessing

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methods of the measurement data and adopted a data leveling method using the first quartile according to past test results and the like. This was done because measurement data includes fluctuation shown in Fig. 1 due to external disturbance.

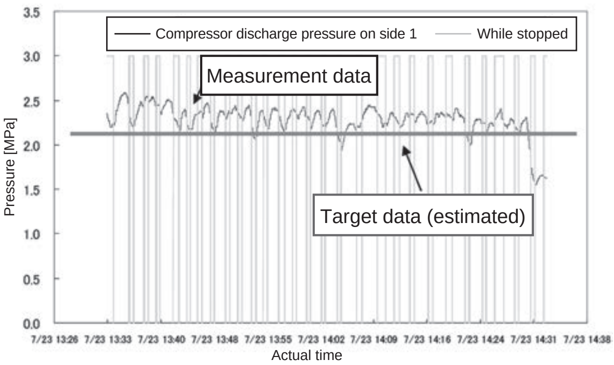

Fig. 1 Fluctuation of Measurement Data Due to Train Operation

5.2 Data Analysis Method

5.2.1 Analysis Based on the Mahalanobis Distance

To quantitatively identify change of collected data, we calculated the Mahalanobis distance of the measurement data of rating tests (before installation on the train) and of tests during operation. Table 3 shows the calculation results.

Table 3 Comparison Between Rating Tests and Field Tests

Rating test in fiscal 2011		Date	Data measured when installed on train (compressor on side 1)		Data measured when installed on train (compressor on side 2)		Data measured when installed on train (compressor on side 3)		Data measured when installed on train (compressor on side 4)	
Case	MD		Case	MD	Case	MD	Case	MD	Case	MD
1	627	3rd week of June	1	598	1	989	1	6616	1	11780
2	594	1st week of July	2	1976	2	990	2	2965	2	6979
3	593	2nd week of July	3	1345	3	646	3	664	3	1775
4	591	3rd week of July	4	1915	4	671	4	556	4	1091
5	623	4th week of July	5	1391	5	771	5	660	5	1898
6	619	5th week of July	6	1283	6	722	6	1177	6	2198
7	648	1st week of August	7	1658	7	678	7	703	7	1743
8	654	2nd week of August	8	1273	8	543	8	752	8	1883
9	651	3rd week of August	9	1391	9	593	9	708	9	1894
10	658	4th week of August	10	1927	10	1002	10	1243	10	2650
11	687	1st week of September	11	1925	11	1138	11	1348	11	3290
12	655	2nd week of September	12	1500	12	816	12	1555	12	3280
13	654									
14	685									
15	721									
16	721									
17	718									
18	717									
19	682									
20	678									
Max. value	721									

The table revealed that the measurement data collected in the tests during operation shows higher values in almost all test cases compared with that of rating tests. It can be assumed that the change from the initial values occurred due to use of the air conditioner for a year. The deterioration level is now under investigation in detail.

5.2.2 Analysis Using a Mollier Chart

Next, we evaluated the data collected during commercial operation using a Mollier chart (p-h chart), which can indicate conditions of refrigerant not visible and equipment phenomena for equipment having a refrigerating cycle. We thus made analysis using that chart. Fig. 2 shows a comparison between measurement data of the rating tests and the field tests. Some slight change in the measurement data of the field tests over that of the rating tests can be found, but obvious deterioration due to contamination is not seen because the field test period was short. If contamination becomes more severe, the Mollier chart will indicate the effects of that.

6 Conclusion

Aiming to identify deterioration level and signs of failure of air conditioners of trains in operation, we carried out a field test and investigated an analysis method of the collected data. As preprocessing of collected data, we applied a leveling method with the first quartile and judged deterioration level based on analysis with the Maharanobis distance. We further analyzed the data using a Mollier chart and found some change in the data for a year.

Results of analysis demonstrate that identification of the deterioration level can be expected by calculating the Mahalanobis distance of the appropriately preprocessed monitoring data and visualized data using the Mollier chart. We plan to refine the data preprocessing method and the analysis method in the future with an aim of putting it into actual use.

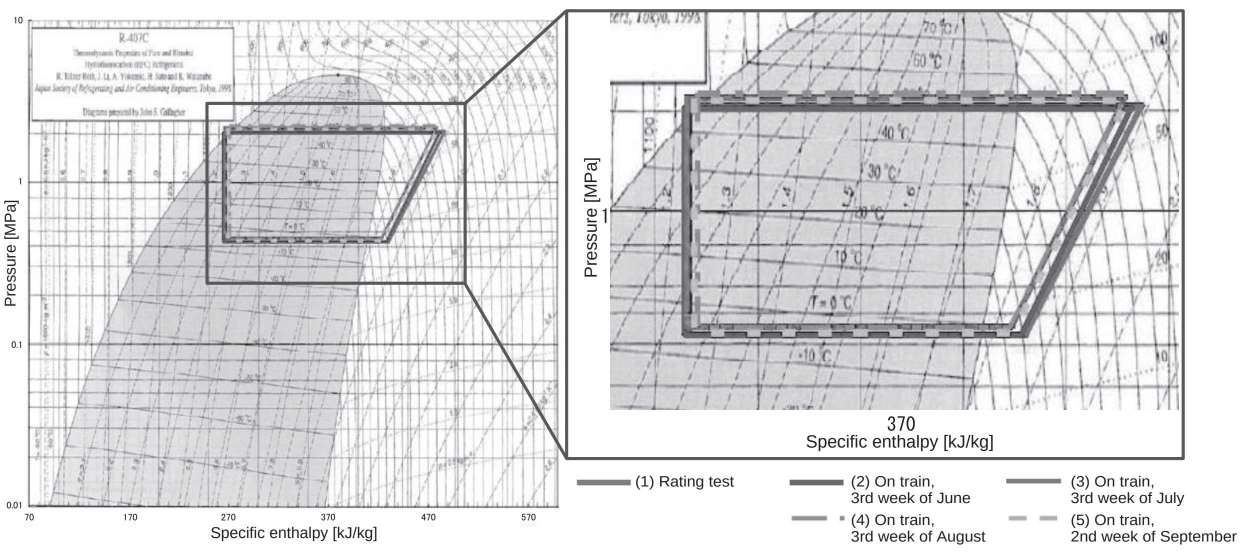

Fig. 2 Example of Analysis Using Mollier Chart