FDC of Wafer Handling Robot Based on Neural Network with Harmonic Sensor - Kenta Kamizono

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1. Introduction

In the manufacturing of semiconductor devices, the most effective Fault Detection and Classification (FDC) for preventing processing defects was developed primarily as a monitoring technology for keeping track of the sensor data of processing chambers. In order to further improve the productivity of manufacturing equipment, it is indispensable to monitor the conditions of all the manufacturing equipment and not just the processing chambers. To this end, Condition Based Monitoring (CBM) is an effective means of performing low-cost maintenance while at the same time preventing processing defects. The common methods of implementing CBM for wafer transfer robot include vibration[1)] and electric current diagnosis; however, it is difficult to make an accurate assessment if there is excessive interference from ambient vibrations (from other axes) and operating conditions (rotation speed, torque, etc.). Furthermore, the development of a deductive judgment algorithm for each degradation mode is extremely time-consuming and expensive. In order to resolve this problem, we have developed a robust machine learning based degradation diagnosis technology, which uses harmonic sensors that can effectively handle multi-axis equipment generating excessive disturbances.

2. Approach: Merits and flow of degradation diagnosis technology

Adhesive wear is a form of abrasive deterioration of machine elements and components, in which the absence of an oil film causes abrasion of the sliding surface resulting in vibrations. These vibrations of the sliding surface change the angular velocity of the motor rotation direction, which in turn changes the motor current (Figure 1). The degradation diagnosis technology uses a motor current system that is not easily affected by ambient vibrations. Data is collected by harmonic sensors with frequency characteristics that have high sensitivity to degradation and low sensitivity to torque, and the waveform patterns are assessed by an unsupervised neural network (NN). By using this approach, an anomaly detection model that is not easily affected by operating conditions can be developed in a short time. Figure 2 shows the deterioration level calculation flow. The harmonics data is input, and after the frequency analysis, the trained NN model makes an inference with only the valid motion part data that is not a noise (Figure 3). Consequently, the anomaly level (= level of degradation), which represents the deviation from normal data, is output.

3. Results: Gear abrasion degradation diagnosis of wafer transfer robot

In a batch-type ion implanter, a sensor for collecting the harmonics output was attached to the wiring between the controller and each motor of the wafer transfer robot (Figure 4), and the output during wafer transfer was monitored. The wafer transfer arm (Figure 5) dropped the wafer while transferring it to the disk inside the processing chamber of the ion implanter, which is considered an error. Figure 6 shows the shift in the mean value of degradation before and after the error. Only normal data collected one year before the error occurred was used as training data. The lower illustration of Fig. 6 shows that the level of degradation is gradually increasing but starts decreasing after changing the gear. (The gradual decrease during transport tests after the change may be indicative of initial run-in.) The deterioration in lubrication performance of the gear's grease may have caused abrasive degradation. When the concentration of iron powder in the grease of the removed gear was analyzed to examine the actual progress of abrasive degradation, it was found to be about 20 times the detection limit (Table 1). This shows that abrasive degradation leads to the accumulation of iron powder in grease.

4. Summary

The example of wafer transfer robot in the ion implanter shows that abrasive degradation of gears can be detected from the level of degradation output by the machine learning based degradation diagnosis system with a harmonic sensor. By performing FDC for the level of degradation, we may be able to implement CBM for wafer transfer robot.

References

1) Peng Chen, (2009) Foundation and application of condition diagnosis technology for rotating machinery, Sankeisha Co. Ltd.

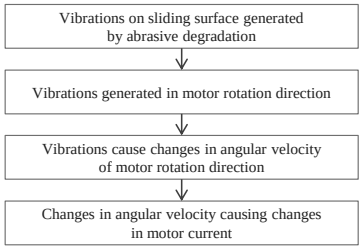

Figure 1. Changes in motor current caused by equipment degradation

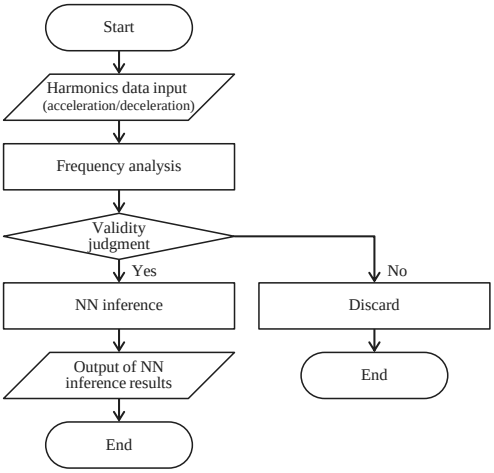

Figure 2. Degradation calculation flow

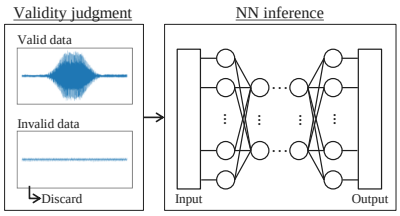

Figure 3. Overview of NN analysis

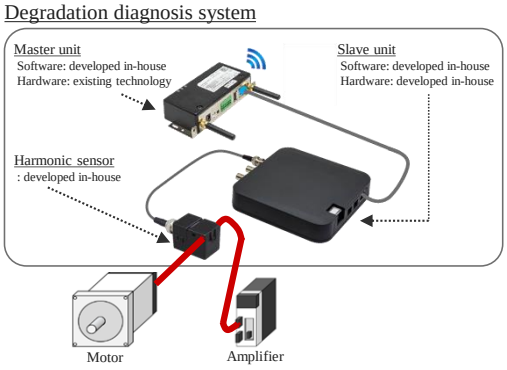

Figure 4. Degradation diagnosis system with harmonic sensor

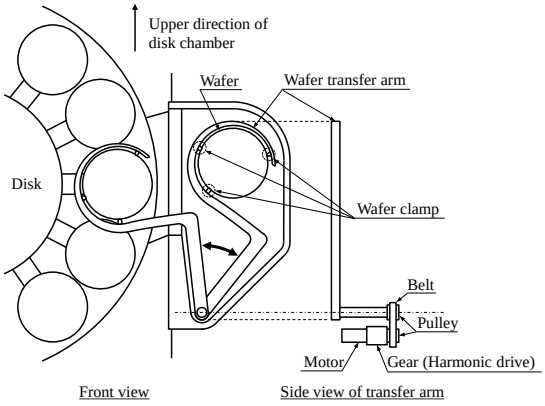

Figure 5. Overview of wafer transfer arm

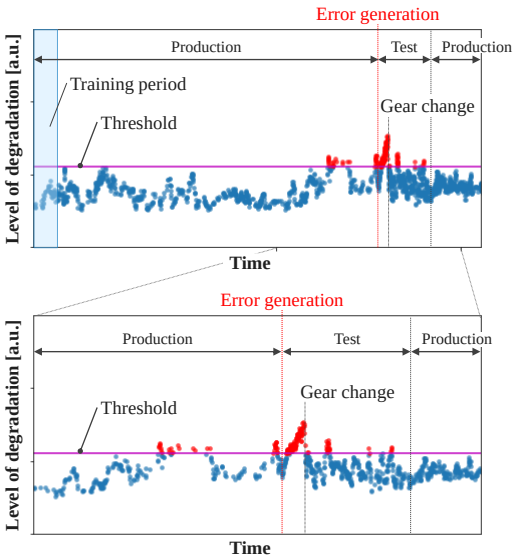

Figure 6. Transition of mean degradation level

Table 1. Analysis results of metallic elements in grease (excerpt)

Unit: mass%

Chemical element \ Specimen	Grease adhering to harmonic gear
Li	0.05
:	
Fe	0.4
Co	<0.02
Ni	<0.02
Cu	0.2
Zn	0.2
:	
Mo	0.2