IJESMR
International Journal OF Engineering Sciences & Management Research

DEVELOPMENT OF RELIABILITY ASSESSMENT TECHNIQUE FOR WAFER TRANSFER ROBOT

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Keywords: *Wafer Transfer Robot, Repeatability, Reliability Assessment, Failure Analysis, Accelerated Model*

ABSTRACT

Semiconductor process that requires high accuracy is subjected to severe impact by slight impact or some impurities. Furthermore, it has more difficult to maintain the basic performance under the extreme operating conditions like a vacuum, high temperature, etc. The wafer transfer robot is a precise control robot for accurately pass the semi-finished product(wafer) to a next process in the semiconductor display production line. This equipment should have stability at high temperatures and ~~to~~ can detect the loading state of a wafer. Reliability of the robot is directly related to the reliability of the manufactured semiconductor. In this paper, the failure analysis materials for the wafer transfer robot was drew up and determined the tests items, and calculated the accelerated life test time for reliability assessment. And, the main performance tests of the improved wafer transfer robot were performed, and the results were analyzed.

INTRODUCTION

The ATM robot consists of a Z-axis that moves the entire structure up and down, a T-axis that rotates the arm at some angles, and an R-axis (with one or two axes) that transfers the wafer to the actual equipment or process stage. All axes are basically based on servo motor control, and the Z-axis converts the rotational motion into a linear motion with a ball screw. The T axis moves the rotating body by increasing the output using a speed reducer, and the R axis is a structure having a binding force in the form of a link, which converts rotational motion into linear motion and performs its function. Failure of the wafer transfer robot in a semiconductor process that requires high precision causes serious problems in the entire semiconductor production line.

In this paper, the major failure and causes of wafer transfer robot are analyzed and test items for reliability evaluation are determined. In addition, the acceleration factor was determined through the failure mode and the acceleration model was applied to calculate the life test time which is a key part of the reliability evaluation.

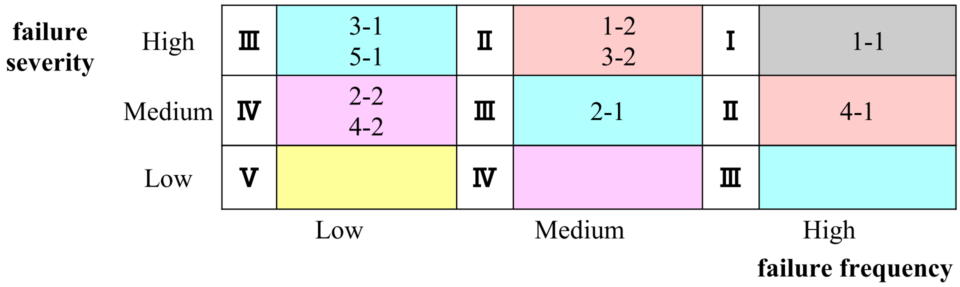
FAILURE ANALYSIS MATERIALS

FMMA(Failure Modes Mechanisms Analysis)

This step finds out and analyzes the major failures of wafer transfer robot by consultant of field users, reference materials, and experts in this field. This step explains the components of wafer transfer robot and their each functions and present failure and failure mechanisms of each component. Table 1 describes this step [1-2]

Table 1: Failure Modes Mechanisms Analysis.

primary components	function	failure modes	failure mechanisms	
Ball screw	Transfer of power, Speed/Torque adjustment	wear	1-1	Fatigue, Overload
		deformation	1-2	Overload
Timing belt	Transfer of power	wear	2-1	Overload, Fatigue
		breakage	2-2	Overload, Fatigue
Robot hand	Transfer of wafer	deformation	3-1	Overload
		Arm breakage	3-2	Overload, lack of hardness
Bearing	Connection & Support between shaft and housing	wear	4-1	Overload, Degradation
		deformation	4-2	Fatigue
Housing	Reducer protection, Fix of equipment	deformation & breakage of the housing	5-1	Excessive load, Repeated impact



failure severity						
High	Ⅲ	3-1 5-1	Ⅱ	1-2 3-2	Ⅰ	1-1
Medium	Ⅳ	2-2 4-2	Ⅲ	2-1	Ⅱ	4-1
Low	Ⅴ		Ⅳ		Ⅲ	
	Low		Medium		High	

failure frequency

Notice : Criticality(score) Ⅰ(9) → Ⅱ(7) → Ⅲ(5) → Ⅳ(3) → Ⅴ(1)

Fig 1 : Criticality Matrix Analysis

FMECA(Failure Modes, Effects, and Criticality Analysis)

FMECA is explained the major failures of primary components of wafer transfer robot and influence of their effects on the whole system, and criticality for each items. Especially, criticality analysis is expressed the severity and failure frequency according to the procedures of MIL-STD-882D for showing the severity distribution in viewpoint of quality[3].

Table 2: Failure Modes, Effects, and Criticality Analysis.

Primary components	function	failure mode	failure mechanism	Failure causes	effects	criticality		
						frequency	severity	criticality
Ball screw	Transfer of power, Speed/Torque adjustment	wear	Fatigue, Overload	Overload, rising temp., fatigue	Vibration, noise, accuracy decline	H	H	9
		deformation	Overload	Foreign substance	Vibration, noise, accuracy decline	M	H	7
Timing belt	Transfer of power	wear	Overload, Fatigue	Overload	Vibration, accuracy decline	M	M	5
		breakage	Overload, Fatigue	Assembly badness	Vibration	L	M	3
Robot hand	Transfer of wafer	deformation	Overload	Overload, abnormality of materials	Operation trouble	L	H	5
		Arm breakage	Overload, lack of hardness	Overload, fatigue	Operation trouble	M	H	7
Bearing	Connection & Support between shaft and housing	wear	Overload, Degradation	Overload	Operation trouble, rising temp.	H	M	7
		deformation	Fatigue	Overload	Operation trouble	L	M	3
Housing	Reducer protection, Fix of equipment	deformation & breakage of the housing	Excessive load, Repeated impact	Overload, fatigue	Abnormal vibration, impossibility of operation	L	H	5

FTA(Fault Tree Analysis)

FTA expresses the cause and generation process of a failure as the type of tree branch in order to reduce the examination time of failure causes. Fig. 2 shows a FTA of wafer transfer robot. The contents marked circle are causes of the failure about each primary components and contents marked rectangular are phenomena of failure which generated by causes of the failure and the primary components happened fault. The causes are combined by OR gate in case of component having multiple causes.

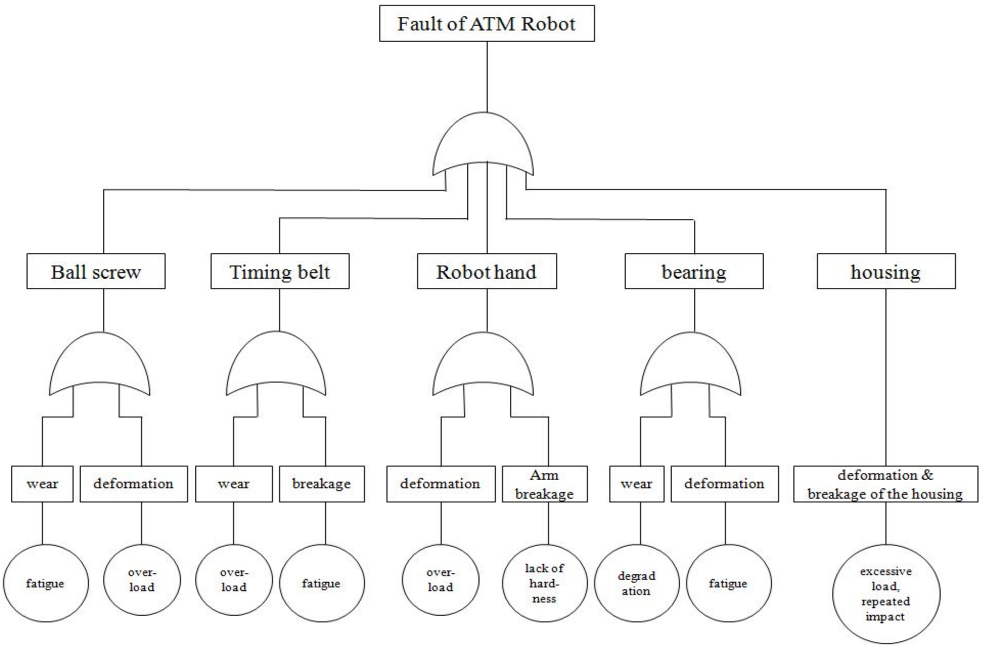


Fig2 : Fault Tree Analysis

2-STAGE QFD(Quality Function Development)

The first stage of QFD expresses the required function at each primary components and failure modes corresponding to them. At that time, the proper score which is assigned by important level is given to the each failure modes. The result is shown in the Table 3. By the results of the first stage of QFD, the main test items are decided in the second stage of QFD. The main test items require the caution for decision because the performance of wafer transfer robot is directly evaluated by them. Table 4 represent the analysis results.

Table 3: 2-Stage Quality Function Development level 1.

Primary components	Ball screw		Timing belt		Robot hand		Bearing		Housing
Failure modes requirements	wear	deformation	wear	deformation	deformation	Arm deformation	wear	deformation	deformation & breakage
Operation ability	◎	◎	◎	●	●	●	●	◎	●
Efficiency of power transfer	◎	◎	●	◎			◎	◎	
Noise	◎	◎	●	●			●	●	▲
Break ability	●	●					◎	◎	
Performance maintenance	●	●	●	●	●	●	●	●	
Corrosion resistance			●						◎
Low vibration	◎	◎	●	▲			●	●	▲
Life	◎	●	●	●	●	▲	●	▲	▲
Importance	31	29	23	18	9	7	25	25	11

score									

Table 4: 2-Stage Quality Function Development level 2.

Primary components	Failure modes	score	Test items				
			Measurement of hand edge deflection	Measurement of operation area	repeatability	Vibration during the transportation	life
Ball screw	wear	31	▲	◎	◎	▲	◎
	deformation	29	▲	◎	◎		◎
Timing belt	wear	23	▲	●	◎		◎
	deformation	18	●		◎		◎
Robot hand	deformation	9	◎		●	●	●
	Arm breakage	7	◎	●	◎	●	◎
Bearing	wear	25	●	●	●		●
	deformation	25	●		●	▲	◎
Housing	deformation & breakage	11		▲	▲	●	●
test effectiveness score and rank			367	476	728	137	800
			4	3	2	5	1

CONCLUSTION OF LIFE TEST TIME

No-Failure Life Test

Domestic industries surveyed ATM robot for wafer transfer conditions the lifetime of the field by considering the 80% confidence level B_{10} life of 5.0*10^5 cycles that were guaranteed. According to the result of life distribution analysis, shape parameter is 6.32. Reliability standards for the evaluation of ATM robot for wafer transfer in the prescribed lifetime of 5.0*10^5 cycles (B_{10} life) means to guarantee the following.

-Lifetime distribution : Shape parameter(β) 6.32Weibull distribution[6]
- Insurance life : 5.0*10^5 cycles (B_{10} Lifetime)
- Confidence level : 80 %
- Prototype : 1ea

At this point, no-failure test time was calculated (1) using, the result is 7.7*10^5 cycles.

$$t_n = B_{100p} \bullet \left[\frac{\ln(1-CL)}{n \bullet \ln(1-p)} \right]^{\frac{1}{\beta}} \qquad (1)$$

$$t_n = 5.0 \times 10^5 \bullet \left[\frac{\ln(1-0.8)}{1 \bullet \ln(1-0.1)} \right]^{\frac{1}{6.32}} \cong 7.7 \times 10^5 \, cycles$$

Accelerated Model

However, because no-failure test time is too long to accelerate the model chosen, and accelerated life test of time should be calculated. Accelerated life test can reduce the overall development time by shortening the production verification time. And it may be ultimately able to reduce the development costs. In this paper, the axial load is adopted as a acceleration factor, and acceleration model and accelerated life test time were calculated as equation (2), (3), respectively[4]. $AF = \left(\frac{F_{test}}{F_{field}} \right)^m = \left(\frac{F_{rated}}{0.75 F_{rated}} \right)^{3.0} = 2.37$ (2)

Where, AF :acceleration factor, F_{test} :acceleration condition load, F_{field} :field condition load, F_{rated} :rated load, m :acceleration index .

Accelerated life test time(t_{na}):

$$t_{na} = \frac{t_n}{AF} = \frac{769,681.76}{2.37} = 324,759.92 \cong 330,000 cycles \qquad (3)$$

MAIN PERFORMANCE TESTS

Some kinds of test are needed to confirm the performance of an improved model of wafer transfer robot, the most important test item is repeatability test in them. So, the test results for repeatability is representatively presented in this digest paper, and others will be presented in the full paper. When each measuring 1,000 times by the drive direction, the precision accuracy according to driving directions shall be not less than all of ±0.1 mm.

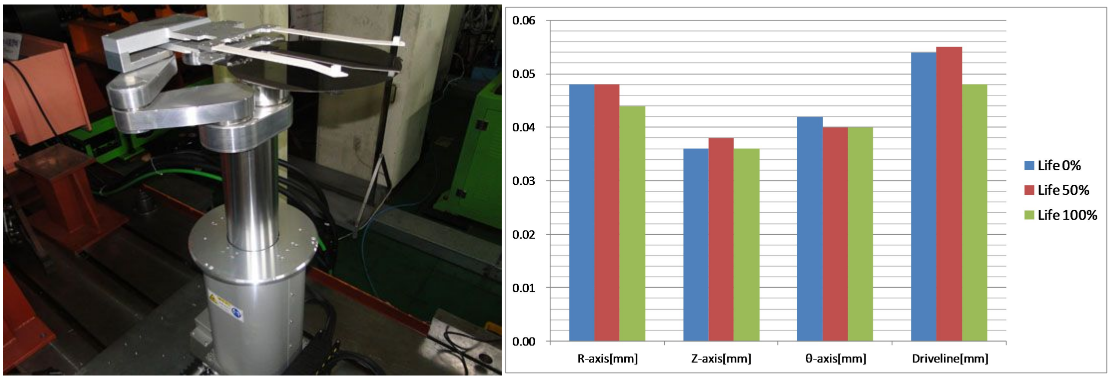


Fig 3 : Result of Repeatability Test

CONCLUSION

This paper proposes the reliability assessment techniques including failure analysis materials, acceleration model, and accelerated life test time for the wafer transfer robot. Some kinds of main test items are determined, and performance test result show for the improved product by use of the main test items.

REFERENCES

1. *Heinz P. Bloch, Fred K. Geitner, Machinery Failure Analysis and Troubleshooting, Gulf Publishing company.*
2. *Logistics Engineering Technology Branch Carederock div, Hand book of Reliability Prediction, 1998.*
3. *MIL-STD-882D, Standard Practice for System Safety, Agencies of the Department of Defense, U.S.A., 2000.*
4. *NSWC, 2007, Handbook of reliability prediction procedures for mechanical equipment, Naval Surface Warfare Center Carderock Division, Maryland .*