Error Calibration and Real Time Compensation System for the Chip Mounting Machine using the Kinematic Ball Bar

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1. Introduction

The chip mounting machines or the PCB chip mounters are widely used in variety of semiconductor manufacturing processes, where those chip mounters are for picking up electronic parts(called chips) from magazines loaded, then for inserting those chips into the PCB(Printed Circuit Board). The static/dynamic accuracy in the positioning/inserting processes plays great role in the performance of the chip mounters, and thus the accuracy enhauncement of the chip mounters has been desired for the manufacturers and users of the chip mounting machines. The laser interferometer or manufacturers' jig have been used for just simple checking of the machine positioning, although more comprehensive error calibration and compensation system is desired. The ball bar system has been used for quick check of accuracy of machine tools, and the comprehensive volumetric error calibration is possible with the enhaunced version of ball bar such as AVEC-100[1]. In this paper, a comprehensive error calibration method is proposed for the chip mounter, where positional errors, squareness error, straightness errors, angular errors, and the back lash error terms are assessed. The chip mounter is modeled with the kinematic configuration, and the volumetric error equations are derived from the kinematic chain of axis configuration. As the backlash error is observed as varying with the axis positioning, a new concept of two dimensional back lash error terms are considered and modeled accordingly. The modeled error terms are effectively added to the volumetric error equations of ball bar analysis algorithm developed, and thus efficient error calibrations are performed. Once the error calibration is performed, the real time error compensation procedures are followed and implemented in the chip mounter controller. The accuracy of chip mounting capability is enhaunced as much as three times in average, and thus the machine performnace is upgraded in terms of accuracy specification. As the on line measurement/compensation features are fully implemented, the developed techniques are readily applied to the manufacturing processes of chip mounters in SAMSUNG, and the acuracy enhauncement is performed.

2. Error Calibration and Modeling

2.1 Error modeling with kinematic ball bar system

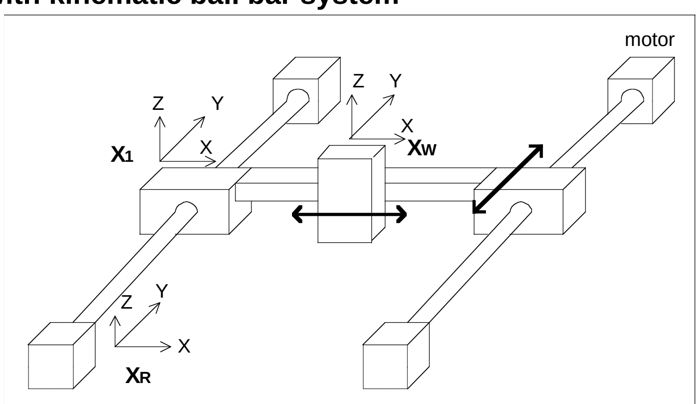

Fig 1.Machine Coordinate of Chip Mounter

Fig 1 shows the configuration of the chip mounter considered, where it has two guides along the Y axis, and the X axis guide on the gantry structure locating on the Y axis guides. Therefore two dimensional kinematic error models are possible, and the translational/rotational error terms are modeled as follows,

$$L(x) = \begin{bmatrix} x + \delta_{xx} \\ \delta x \end{bmatrix} \quad (2\text{-}1) \qquad L(y) = \begin{bmatrix} \delta \quad -\alpha y \\ y + \delta_{yy} \end{bmatrix} \quad (2\text{-}2)$$

$$R(x) = \begin{bmatrix} 1 & -\varepsilon_{zx} \\ \varepsilon_{zx} & 1 \end{bmatrix} \quad (2\text{-}3) \qquad R(y) = \begin{bmatrix} 1 & -\varepsilon_{zy} \\ \varepsilon_{zy} & 1 \end{bmatrix} \quad (2\text{-}4)$$

The following formula are induced from the structure of chip mounter..

$$X_R = R(y) X_1 + L(y) \quad (2\text{-}5)$$

$$X_1 = R(x) X_W + L(x) \quad (2\text{-}6)$$

From (2-5), (2-6) X_W is like

$$X_W = R(x)^{-1} \left[R(y)^{-1} \left[X_R - L(y) \right] - L(x) \right] \quad (2\text{-}7)$$

Using translation & rotation matrix(2-1~4) errors can be derived.

$$\Delta X = \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} = \begin{bmatrix} -\delta_{xx} - \delta_{xy} - \alpha y - \varepsilon_{zy} y - \varepsilon_{zx} y \\ -\delta_{yy} - \delta_{yx} - \varepsilon_{zx} x \end{bmatrix} \quad (2\text{-}8)$$

The relation ship between the radial error and the volumetric error is then as follows,

$$(R + \Delta R)^2 = (x + \Delta x)^2 + (y + \Delta y)^2 \quad (2\text{-}9)$$

thus the radial error is formed as following.

$$\begin{aligned} \Delta R &= \frac{1}{R}(x \Delta x + y \Delta y) \\ &= \frac{x}{R}(-\delta_{xx} - \delta_{xy} - \alpha y - \varepsilon_{zy} y - \varepsilon_{zx} y) + \frac{y}{R}(-\delta_{yy} - \delta_{yx} - \varepsilon_{zx} x) \end{aligned} \quad (2\text{-}10)$$

Eq(2-10) completes the error calibration of the chip mounter using the kinematic ball bar, and it can be used for the consequent error calibration/compensation procedures.

2.2 Compensation algorithm

The compensation algorithm calculates the compensation values from present and target coordinates and make the chip mounter move to the accurate position. The compensation value is determined by a machine controller using the following compensation formula, which is derived from the modeling information of X-Position Error, Y-Position Error , Y-Yaw Error, Y Straightness Error along X axis, X straightness Error along Y axis, X-Backlash, Y-Backlash.

The compensation formula defined by the structure of chip mounter are

$$\Delta X = \delta\, \mathrm{x(X)} - \delta\, \mathrm{x(Y)} + \mathrm{Backlash\_X(X,Y)} \quad (2\text{-}11)$$

$$\Delta \mathrm{Y} = -\delta \mathrm{y(X)} + \delta \mathrm{y(Y)} + \alpha\, \mathrm{X} + \varepsilon_{zy} \mathrm{Xp} + \mathrm{Backlash\_Y(X,Y)} \quad (2\text{-}12)$$

where the backlash terms are explained in the next sections.

3. Practical application

3.1 Configuration and Method of Experiment

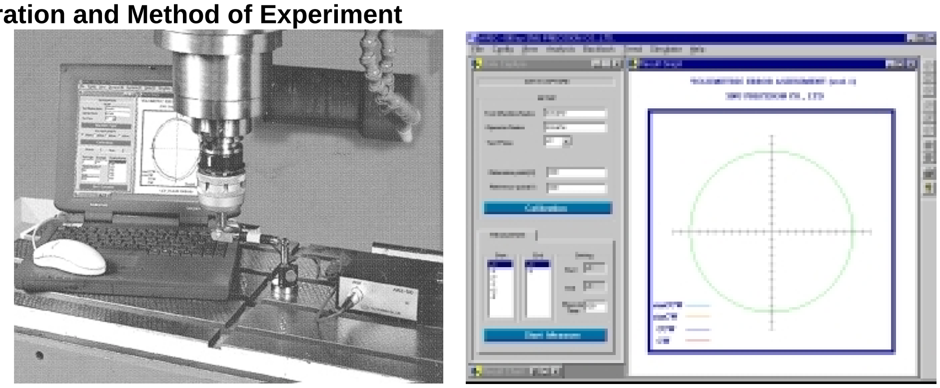

Fig 2. Ballbar System

The developed AVEC-100 ball bar system has been applied to the Samsung chip mounter(Model name :

CP-40), where the ball bar setup and configurations are shown in fig2.
In this experiment, the kinematic ball bar of 300mm radius(nominal length) and Invar calibrator is used to guarantee the length accuracy. A PC is connected to kinematic ball bar via sensor interface part and the controller of chip mounter by RS232C interface module to receive the signal that chip mounter moves to the measuring position and takes the data from kinematic ball bar at that time. The measurement procedures are performed along the contour path based on the point to point to movement of the chip mounter.
The backlash error is varying at the every point of X-Y plane because the yaw error along Y axis is great by the effect of the gantry type structure of chip mounter, where a drive motor is attached to only one ball screw. The kinematic ball bar (AVEC-100) software makes two dimensional backlash error from the measurements as follows.

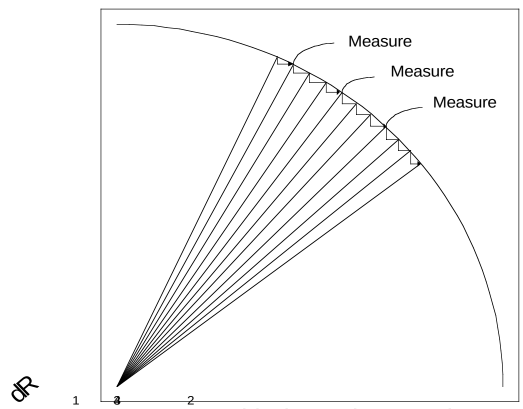

Fig 3 . Ball Bar Measurement with the Point to Point Movement of Machine

3.2 The Measurement and Modelling of Backlash

As is seen in Fig 4, backlash can be obtained by movement to the X+, X-, Y+, Y- direction at each measuring point around the circle. The formula (3-1) and (3-2) show the backlash modeling function out of measured backlash values with variables X, Y.

$$Backlash\_X(X,Y) = AX + BY + CXY + D \quad (3\text{-}1)$$

$$Backlash\_Y(X,Y) = A'X + B'Y + C'XY + D' \quad (3\text{-}2)$$

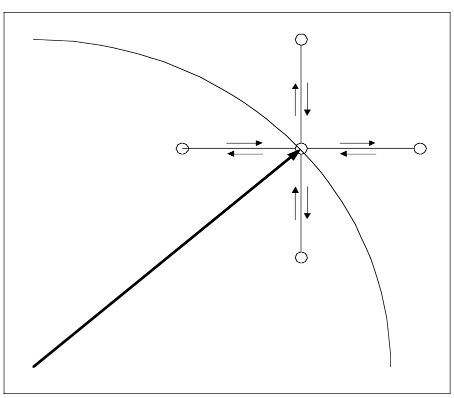
Fig4. Backlash Measurement

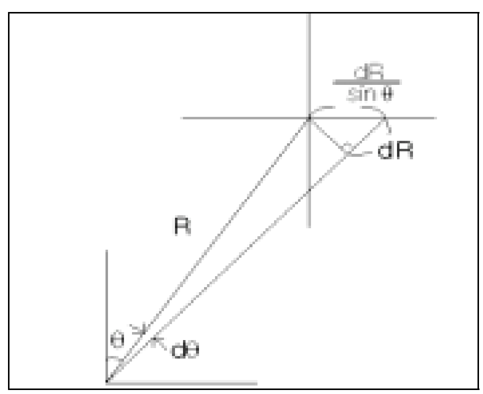

Fig 5. Backlash Analysis

3.3 Results

Using the kinematic ball bar, the errors of chip mounter are measured, calibrated, and compensated. To certify this effort, the errors are measured again after calibration. Also the pitch error along X, Y axis of the chip mounter are measured by the laser interferometer before and after compensation. As a result, we can see that accuracy of chip mounter is improved about 3 times. Fig 6, 7 show the measurement result of kinematic ball bar and Fig 8, 9 is the result of laser interferometer measurement before and after compensation. Table 1 shows the comparison of accuracy with and without compensation.

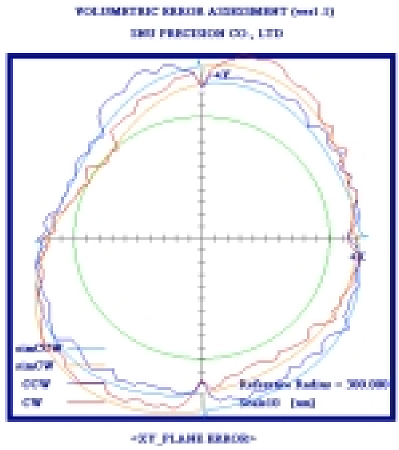

Fig 6. Before compensation

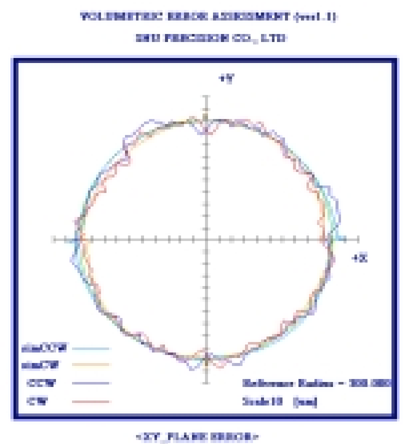

Fig 7. After compensation

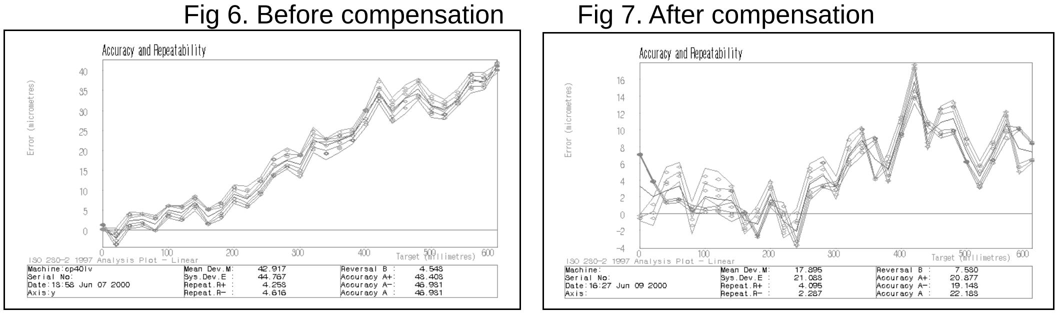

Fig 8. Compensation Result (X Axis)

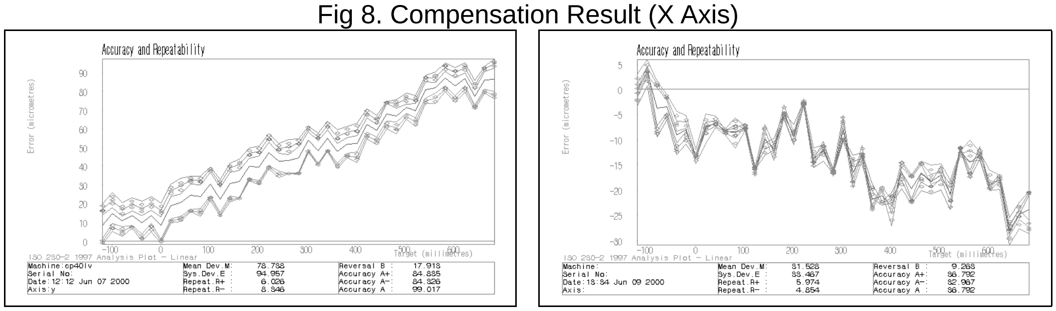

Fig 9. Compensation Result (Y Axis)

	X axis		Y axis	
	Accuracy	Backlash	Accuracy	Backlash
Before Compensation	46.931	4.548	99.017	17.913
After Compensation	22.183	1.530	36.792	9.263

Table 1. Compensation Result

4. Conclusion

A kinematic ball bar system is applied to semiconductor equipments such as chip mounter, where the PC controls the kinematic ball bar and controller of chip mounter using RS232C interface. Thus the on-line features of measurement/compensation is implemented. The accuracy has been enhaunced as much as about three times, and the machine accuracy specification has been uograded.

References

[1] AVEC-100 User Manual for Ball Bar System, SNU Precision, 1999

[2] A new technique for volumetric error assessment of CNC machine tools incorporating the ball bar measurement and the 3D volumetric error model, Heui Jae Pahk, Y.S.Kim, J.H.Moon, acceptef for publication to the Int.J.machine tools and manufacture, 1996