Skewness and Kurtosis Risks of Lot Acceptance Sampling Inspection for Semiconductor Manufacturing – Takahiro Ikeda

Kentaro Kasa, Masafumi Asano, Yasuharu Sato and Takashi Sato
ta-ikeda@amc.toshiba.co.jp
Toshiba Corporation
8, Shinsugita-cho, Isogo-ku, Yokohama, 235-8522, Japan
Phone: + -81-45-776-5386 Fax: +81-45-776-4104

Inline inspections are frequently used as effective tools for quality control. In cases of lot acceptance of lithographic metrology, such as critical dimensions and overlay errors, sampling inspection "by variables" is more cost effective rather than that "by attributes" because of it's less sample size.However, the former assumes the normal population whether both critical dimensions and overlay errors do not obey in many cases. Producer's(α) and consumer's(β) risks will increase when the inspection by variables is applied in such cases. There are two types of risks generated by non-normality of the population:

(1) The Skewness Risk[2]: Many populations obey distribution function asymmetric around their means. If one apply the conventional acceptance variable, which assumes symmetric normal population, the variable is overestimated for USL (or LSL) and underestimates for LSL (or USL). Thus different severity of lot acceptance arises for USL and LSL.

(2)The Kurtosis Risk: Tales of normal population spread to the range of (-∞, ∞). On the contrary, Sato et al. have shown that the population of overlay error shows the thin-tailed distribution when the linear errors are dominant[1]. If one apply the conventional inspection by variable, acceptance variables will be overestimated to both USL and LSL. As a result, meaningless rework will increase because of increment of producer's risk.

Previously, we have shown that a new acceptance variable with skewness is effective to reduce the skewness risk[2]. In this paper, we investigated the case that the existence of both skewness and kurtosis. For this sake, we constructed models of population as followings:

1) The exponential power distribution[3]

$$\phi(x) = \frac{1}{2p^{1/p}\Gamma\left(1+\frac{1}{p}\right)\sigma_p} \exp\left(\frac{-|x-\mu|^p}{p\sigma_p{}^p}\right) \ldots (1)$$

In this equation, p is related to the thickness of tail: the tail is thicker when p is smaller. The distribution coincides with normal distribution when p equals to 2.

2) Suppose that c.d.f. of $\phi(x)$ is $\Phi(x)$, then

$$f(x) = 2\phi(x)\Phi(\lambda x) \ldots (2)$$

becomes another probability density function[4].

Here λ denotes shape parameter: $f(x)$ becomes symmetric when λ equals to 0. It becomes strongly asymmetric for it's larger absolute values. Using equations (1) and (2), we can construct the model with various skewness and kurtosis systematically.

Fig.1 shows the simulated results of the operating characteristics of lot acceptance sampling inspections by variables for the models mentioned above. In the figures, dotted curves indicate the case of normal population. It is clearly seen that OC curves varies their shapes in left figures (conventional inspection by variables) for the population with various skewness and kurtosis. This means that there are large values of producer's and consumer's risks except for the case of normal population. On the contrary, inspection by new variables, which is defined by the linear combination of sample mean, sample standard deviation, sample skewness and sample kurtosis, is not affected drastically by the shape of population as shown in the right figures.

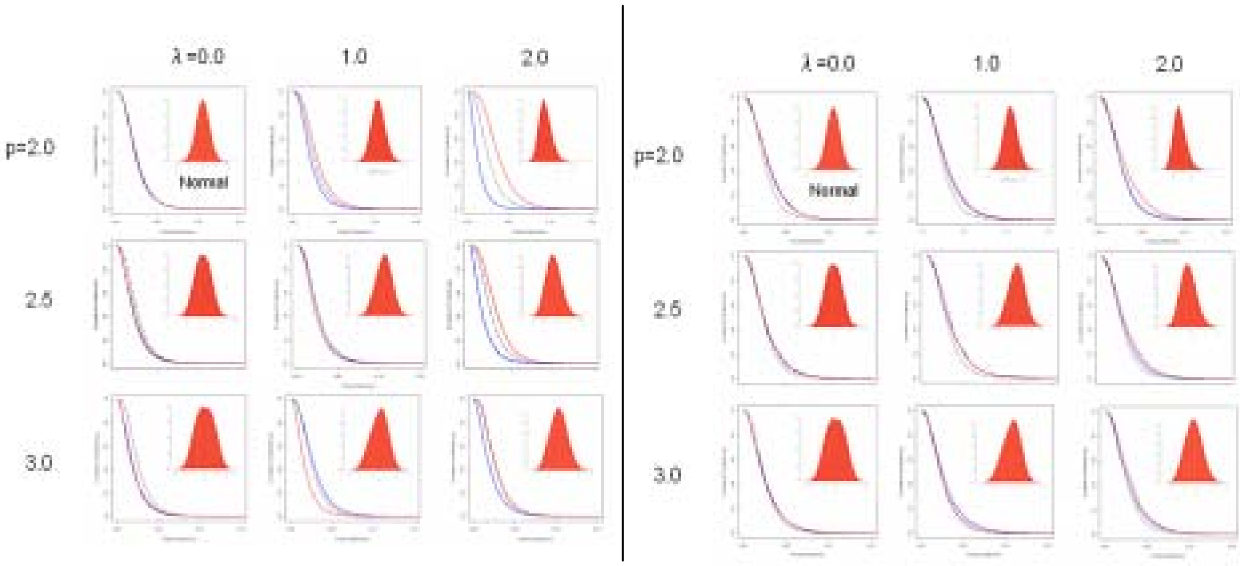
Fig.2 shows the result of application of the new variables for real data of critical dimension of mass production line of which population is strongly skewed. With new variables, skewness risk decreases as shown in the right figure. As a result, we can utilize new sampling inspection by variable avoiding increasing of skewness and kurtosis risks.

1) Y. Sato and T. Sato, Journal of JSPE **69**, 1018 (2003)

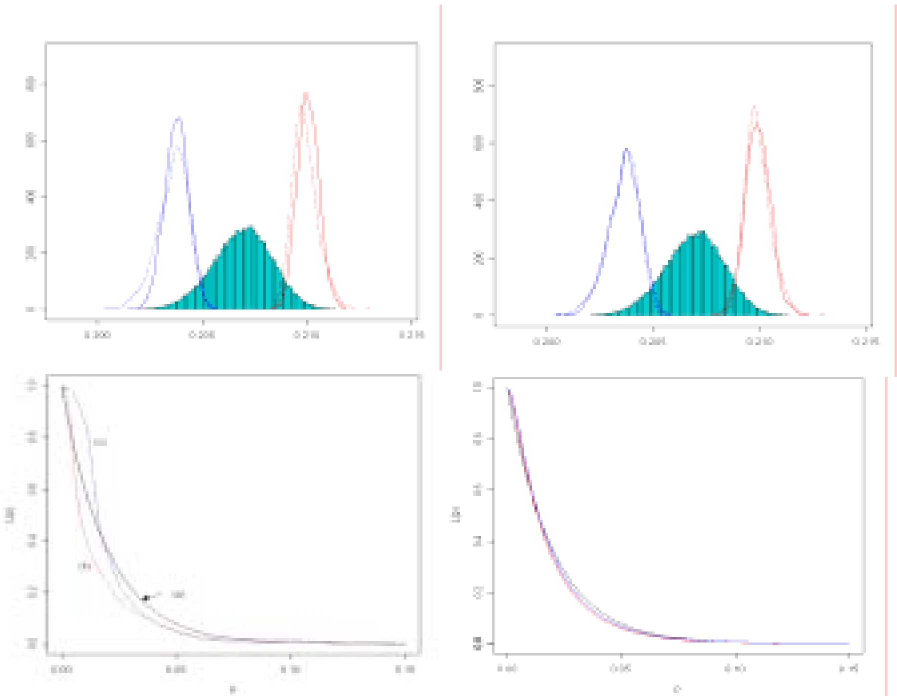
2) T. Ikeda et al : Metrology, Inspection, and Process Control for Microlithography XXII, Proc. SPIE 6922, 692214(2008)

3) M. Th. Subbotin, Matematicheskii Sbornik, **31**,296-301(1923).

４）Azzalini, A. (1985).Scand. J. Statist._ *12*,
171-178(1985).



【Fig. 1】 The OC curves calculated by skewed exponential power distribution. Left: the conventional inspection. Right: the proposed inspection.



【 Fig. 2 】 Operation characteristics for real non-normal populations. Left: conventional inspection. Right: the proposed inspection.