A STUDY OF GAUGE REPEATABILITY AND REPRODUCIBILITY OF THE BACK-END SEMICONDUCTOR LEAD INSPECTION SYSTEM.

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ABSTRACT: Vision inspection systems in semiconductor industries play a major role in the productivity and the quality of the product due to its precise, micro-size and repeating tasks. This is inline with the industrial revolution 4.0 that almost every industry is talking about. It is not about to replace the human operator totally, but rather to design a system or equipment where its performance has less dependent on the operator skills. One of the methods to measure the performance of the equipment is through the gauge repeatability and reproducibily (GR&R). This study focuses on the back-end process in integrated chip (IC) semiconductor industry that involves lead and marking inspection of the chip using our inhouse developed vision system. The inspection is performed after the unit has passed the functionality test. The inspection parameters include marking defects, package defects and lead defects. Out of these three defects, we focused on the lead length defect in which the inspection system would measure the lead length for 10 sample units of SOT89 package by three diffrent operators from different shifts. The result shows that the value og GR&R is 0.037 (25.51%) which is consider within the acceptable range of less than 30% and hence the vision inspection system is fit to release to production use.

KEYWORDS: *Vision inspection system, GR&R.*

1.0 INTRODUCTION

Gage Repeatability and Reproducibility (GR&R) study is a measure of the capability of a gage to obtain the same measurement reading everytime the measurement process is undertaken for the same characteristic or parameter(Haleel, Hussein, & Alkareem, 2018). In other words, (GR&R) indicates the consistency and stability of a measuring equipment (Maire, Pillet, & Baudet, 2013) . Mathematically, GR&R is actually a measure of the variation of a gauge's measurement and not of its stability. An engineer must therefore strive to minimize GR&R numbers of their measuring equipment, since high GR&R number indicates instability and thus undesireable. GR&R has two major components, namely, repeatability and reproducibility. Repeatability means the ability of the same gauge to give consistent measurement reading regardless the number of measurements taken by the same operator(Mikulová & Plura, 2018). Reproducibility on the other hand, measures the ability of the same gage to give consistent measurement reading regardless of whom performs the measurements. In both cases, it requires the measurement to be acquired by different opeators under the same condition. There are no exiating gages or measuring devices that give exactly the same measurement readings all the time for the same parameter. There are five major elements of a measurement system, all of which contribute to the variability of a measurement process: 1) Standard, (2) Environment, (3) Instrument, (4) People,

(5) Work piece. All of these factors effect the measurement reading acquired during each measurement cycle, although to variying degrees. Measurement errors, therefore can only be minimized if the errors or variations contributed individually by each of these factors can also be minimized. Still the gauge is at the center of any measurement process, so its proper design and usage must be ensured to optimize its GR&R. The gage and parts variance are then estimated by conducting analysis of variance (ANOVA)(Kazerouni, 2009), the obtained result is compared with the rejection criteria of the precision-to-tolerence ration (PTR).

2.0 METHODOLOGY

In general, GR&R measures the amount of variability induced in measurements that comes from the measurement system itself and compares it to the total variability observed to determine the viability of the measurement system. GR&R ia a vital test that is needed to determine the precision of the system measured in percentage. The lower the value of GR&R the better it is in representing the level of precision of the measurement system. Since the Vision Inspection System is dealing with the lead's length and width measurement, the variations that are related to the measurement must be considered. There are four parameter of variations that makes up the total variation.

(1) Equipment variation (EV) represents the repeatability of the measurement process. It is calculated from measurement data obtained by the same operator from several cycles of measurements using the same equipment.

(2) Appariser Variation (AV) represents the reproducibility of the measurement process. It is calculated from measurement data obtained by different apparisers using the same equipment under the same conditions. R&R is simply the combined variations off EV and AV where ,

$$R\&R^2 = EV^2 + AV^2$$

(3) Part variation (PV) represents the effect of the variation of parts being measured on the measurement process and is calculated from measurement data obtained from several parts.

(4) Total Variation (TV) represents the overall variation exhibited by the measurement system, consists of the effects of both R&R and PV

$$TV = R\&R^2 + PV^2$$

Note that the measurement variations are not only caused by EV and AV but also by PV.

The procedure to setup GR&R testing are as follows.

1. Vision inspection system is calibrated using a standard unit and verified the reading with a profile projector prior to measurement.
2. Three operators are selected to perform the measurement on lead length (pin 1) of the SOT-89 package (the measurement tolerance between 0.7-1.3mm) – refer Figure 1 (dimension H)
3. Ten sample production units are randomly selected and label 1 to 10 accordingly.
4. Each sample is measured by the above operators in the order of 1 to 10 –Trial 1. After finish 10 units, repeat the measurement for trial 2 and trial 3.
5. Then the average of the three operators are computed and record the minimum value and the maximum value as Lower Control Level (UCL) and Upper Control Level (UCL) and also compute the average value of the parts.
6. Run the data in SPC- excel software (http://www.spc-for-excel.com.).

The reference of the lead specification is based on the mechanical drawing provided by the manufacturer as shown in Figure 1

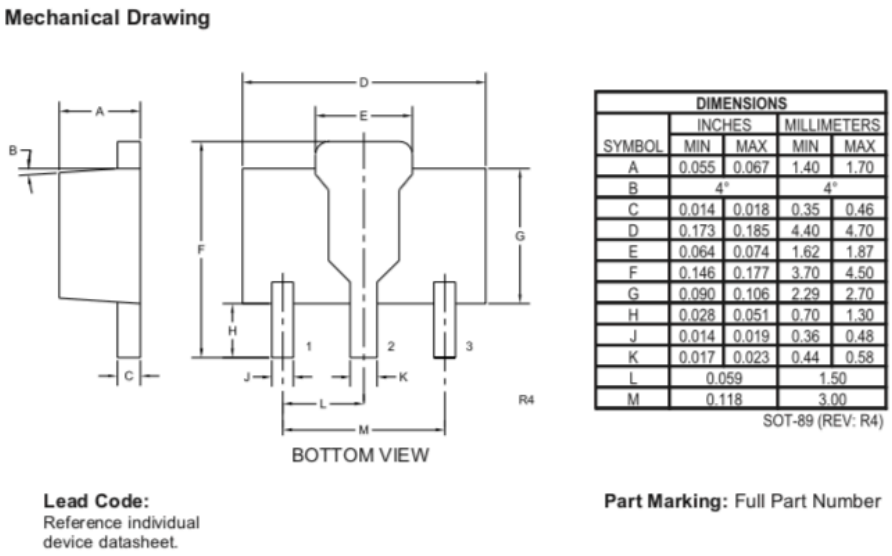

Figure 1 : The mechanical drawing for SOT-89-4L package.

Based on the procedure above, the data obtained were computed and the result of GR&R was measure in percentage. The accepatance criteria for GR&R is stipulated in Table 1.

Table 1: General Acceptance of %GR&R (Cepova, Kovacikova, Cep, Klaput, & Mizera, 2018).

No	GR&R Score(%)	Descriptions
1	< 10%	Acceptable measurement system that provides reliable information about the process changes.
2	10% - 30%:	Conditionally acceptable measurement system. It can be used for some application.
3	> 30%:	Not acceptable measurement system. It does not provide reliable information about the process changes.

2.0 RESULT AND DISCUSSION

Table 2: The measurement data obtained from 10 sample units by three operators.

Date : XX-XX-XXXX						Measurement unit : mm					
Product : SOT-89						Parameter : Lead Length					
Operators : Oper_1, Oper_2, Oper3						Lead # : 1					
Operator	#Trial	Sample Units									
		1	2	3	4	5	6	7	8	9	10
Oper_A	1	1.130	1.148	1.150	1.149	1.149	1.187	1.13	1.138	1.150	1.141
Oper_A	2	1.130	1.149	1.149	1.150	1.150	1.188	1.13	1.141	1.150	1.140
Oper_A	3	1.131	1.150	1.149	1.150	1.150	1.190	1.13	1.139	1.140	1.152
Oper_B	1	1.161	1.151	1.148	1.150	1.150	1.171	1.15	1.131	1.130	1.140
Oper_B	2	1.162	1.149	1.149	1.148	1.149	1.170	1.14	1.130	1.140	1.140
Oper_B	3	1.161	1.149	1.150	1.149	1.148	1.170	1.14	1.132	1.140	1.140
Oper_C	1	1.142	1.140	1.142	1.151	1.151	1.180	1.14	1.130	1.140	1.138
Oper_C	2	1.141	1.139	1.139	1.149	1.149	1.181	1.14	1.132	1.140	1.138
Oper_C	3	1.140	1.138	1.139	1.148	1.159	1.179	1.14	1.132	1.140	1.134

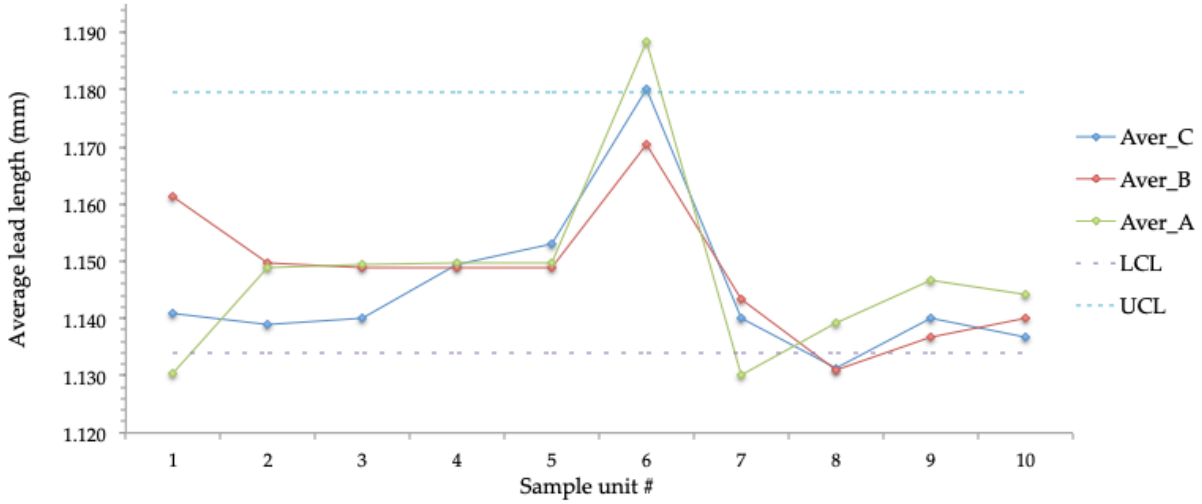

Figure 1: The average measurement obtained from 10 sample units by three operators.

Base on the analysis, the GR&R (%) obtained from SPC excel software, we obtained 25.5% in which based on the acceptance in Table 1, the measurement quality of the system is considered acceptable based on applications, hence can be released to production. This GR&R% value could be improved if the setup can eliminate or reduce the lighting condition as well as to replace with a better camera.

3.0 REFERENCES

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