Statistical Inspection of a Workplace for Adhesive Assembly

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Abstract: *Quality of a workplace for adhesive assembly has been examined using acceptance sampling. The goal of the work has been to find our whether dispensing of electrically conductive adhesive makes forming of adhesive joints with sufficient reliability and repeatability possible. Adhesive joints have been fabricated by adhesive assembly of jumpers. Four types of adhesives, one of an acrylate type and three of an epoxy type with Ag filler have been used for testing. Joints resistances have been measured by a four-point method. Acceptance sampling by attributes has been used for statistical inspection. Acceptance plan has been calculated. It has been found that the workplace does not give results with sufficient quality.*

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1. Introduction

The goal of the inspection is to determine if production is reliable and if its quality is sufficient. With respect to the fact that the measurement of every item (e.g. an electronic component) would be too expensive, statistical methods for inspection have been developed. The use of these methods makes inspection substantially more economical and faster on the one hand; however, on the other hand, the conclusions of statistical inspection are not sure, the are valid by some probability only.

There are many different programs and strategies for production quality control – ISO 9000:2000, TQM, S4 (Smart Six Sigma Solution), Kaizen and many others, and many different tools for statistical inspection of production quality. The basic group of statistical production control tools has been defined by Ishikawa – Seven Ishikawa Tools.

One group of methods of statistical inspection is focused at decision if accept or reject a lot delivered from a supplier. A lot is defined as a quantity of items accumulated (fabricated) under uniform conditions.

These methods are called Acceptance Sampling Methods.

It is necessary to stress that the main purpose of acceptance sampling is to decide whether or not the lot is likely to be acceptable. These methods do not make estimation of quality of a lot possible; they support information that the quality of a lot is sufficient.

2. Acceptance Sampling

The goal of acceptance sampling is to avoid 100 % inspection but to have a basis for decision if to accept or to reject the lot. It has been found that a limited number of items (a sample) should be picked at random from the lot, and on the basis of information that has been yielded by this sample a decision should be made regarding the quality of the lot. In general, the decision is either to accept or reject the lot. It has been already mentioned that this decision is made with some, sufficiently high, probability. Therefore it is joined with some risk for customer and for supplier, as well.

The basic result of acceptance sampling is an acceptance plan. Acceptance plans can be categorized across different dimensions:

- Plans by Attributes (Pass–Fail Plans, Conforming–Nonconforming Plans) – the items inspection leads to a binary result. The process is called "sampling by attributes".

- Plans by variables – if the items inspection leads to the measurement of a continuous variable. The process is called "sampling by variables ".

The attribute case is the most common type of the acceptance plans, and has been used for our inspection.

Another categorization of acceptance plans is as follows:

- Plans for incoming inspection – are made with the purpose to decide if the lot can be accepted or if it has to be rejected.
- Plans for outgoing inspection – is related to an agreement between a customer and a supplier. If it is agreed, a supplier realizes an acceptance sampling of an outgoing lot and results of this inspection is taken by a customer as the result of its own incoming inspection. Such the solution is possible under the condition that there are long-term good and reliable relationships between the customer and the supplier.

Acceptance plans can also be categorized from following point of view:

- Rectifying plans – are plans accepting a possibility of substitution of faulty items by good ones, or rework of faulty items. Costs for this substitution or repair are paid by supplier.
- Non-rectifying plans – are the plans where faulty items must not be substituted or reworked.

3. Acceptance Sampling for Attributes

The process of acceptance sampling is defined by standards MIL STD 105E and ISO 2859. Three types of inspection plans are defined:

- Tightened inspection (for a history of low quality) requires a larger sample size than normal inspection.
- Reduced sampling (for a history of high quality and reliability of a supplier) has a higher acceptance number in comparison with normal inspection (so it is easier to accept the batch).
- Normal inspection.

The main result of acceptance sampling is an acceptance plan. It defines a rule for decision if a batch will be rejected or accepted. It consists of two numbers:

- Number of items *n*, which have to be picked at random from the lot (the batch). Sometimes it is spoken about an inspection level. The inspection level determines the relation between the batch size and the sample size.
- The maximum proportion *Ac* or fraction *AQL* of nonconforming (defective) items among picked items.

Acceptance Quality Level AQL is the maximal percent of nonconforming items, which is considered, for inspection purposes, as a satisfying process mean. Different AQLs may be designated for different types of defects. It is common to use an AQL of 1% for major defects, and up to 2.5% for minor defects.

The number of picked items (the level of sampling) influences risk of customer and supplier. If all items of the batch would be inspected, the result would be found with the probability of 100 %. That means with the certainty. However, the principle of acceptance sampling is to investigate a randomly selected sample of the batch. This is the reason, why the conclusions will be joined with some risk for the supplier and for the customer, as well.

The risk α of the supplier describes probability that a good batch will be rejected; the risk β of the customer describes probability that a wrong batch will be accepted. Usually α = 5 %, β = 5 to10 %.

There are also two significant levels of probability joined with the acceptance sampling:

- Probability p1 … acceptable fraction of nonconforming items in the lot.
- Probability p2 … non-acceptable fraction of nonconforming items in the lot.

A significant tool of acceptance sampling is an Operating Characteristic (Fig. 1). The Operating Characteristic shows the probability of acceptance for any level of lot quality. On the horizontal axis is a quality parameter – a fraction of nonconforming joints.

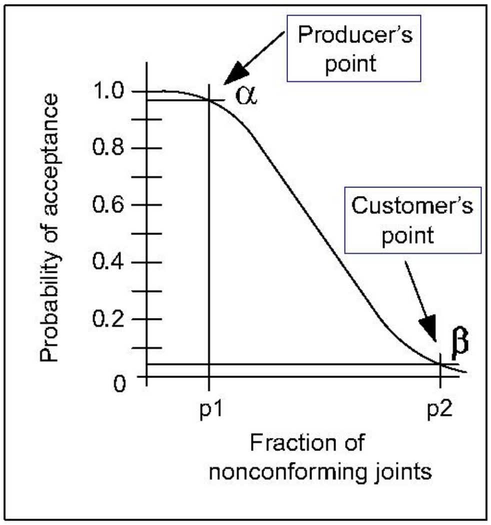

Fig. 1 Operating characteristic

The operating characteristic enables to evaluate probability of acceptance for any lot quality level.

To find out an inspection plan it is necessary to calculate the number of items *n*, which have to be picked, and acceptance number *Ac* using equations:

$$\frac{p_1}{p_2} = \frac{\chi^2_{1-\beta}[2.(Ac+1)]}{\chi^2_{\alpha}[2.(Ac+1)]} \quad (1)$$

$$2np_1 = \chi^2_{\alpha}[2.(Ac+1)] \quad (2)$$

4. Calculation of Parameters of Acceptance Plan

Calculation of parameters of the acceptance plan has been done in following steps:

1. Acceptable and non-acceptable fractions of nonconforming items, (probabilities p1 and p2), have been appointed.
2. The risk α of the supplier and the risk β of the consumer have been appointed.
3. Ratio p1/p2 has been calculated.
4. Into the right side of the equation (1) values Ac =0, Ac = 1 etc. have been substituted and value of the fraction has been calculated.
5. It has been found such the integer Ac, when the right side of the equation (1) has been the nearest number in with respect to the ratio p1/p2.
6. The value of *n* has been calculated using the equation (2).

5. Acceptance Plan for Adhesive Joints

Adhesive joints have been fabricated by adhesive assembly of "zero" resistors (jumpers) on test boards. The resistors have been of a type for adhesive assembly, the surface finish of their contacts has been CrNi/Cu/Ni/Ag. Four types of adhesives with isotropic electrical conductivity have been used; two of them have been of a one-component type, two of a two-component type:

1. Permacol LT8845/3 – one component type, acrylate resin, Ag filler.
2. Elpox SC 515 – one component type, epoxide resin, Ag filler.
3. Elpox AX 15S – two component type, epoxide resin, Ag filler.
4. Elpox AX 12 – two component type, epoxide resin, Ag filler.

Adhesives have been applied by dispensing. The jumpers have been assembled using a semi-automatic pick and place machine.

The resistances of adhesive joints have been measured using a 4-point method. A Precision LCR Meter HP 4284A has been used for the measurement.

Four batches of the joints have been measured. Every batch has contained 200 joints fabricated of one type of adhesive. SW tool QC Expert has been used for testing of normality of the data. Skewness and kurtosis test has been used for this testing. It has been found that the data are normally distributed. Mean value and standard deviation of the batches have been calculated. Then parameters of the acceptance plan have been found.

The steps of calculation have been as follows:

1. The maximum acceptable resistance of the joints has been appointed: R_{max} = 17 mΩ. This value has been appointed without respect to the type of adhesive. The mean values and standard deviations of the batches have been found: R_{mean1} = 12,3 mΩ, σ_1 = 2,71, R_{mean2} = 10,15 mΩ, σ_2 = 3,60, R_{mean3} = 14,2 mΩ, σ_3 = 4,34, R_{mean4} = 12,7 mΩ, σ_4 = 3,38 .
2. Probabilities p1 and p2 have been appointed: p1 = 0,03; p2 = 0,16.
3. The risk of the supplier and the customer has been appointed: $\alpha = \beta = 0,05$
4. The value of the fraction p2/p1 has been calculated: p2/p1 = 5,33
5. The value of Ac has been changed from 0 to 5 by 1 and values of the equation (1) have been calculated (see Tab. 1)

Tab. 1 Calculation of parameters of an acceptance plan

Ac	0	1	2	3	4	5
Eq. (1)	58,16	13,35	7,70	5,67	4,65	3,60

6. The nearest value to the value p1/p2 = 5,33 is the value 5,67. Therefore the acceptance number *Ac* is 3.
7. The number of randomly selected joints has been calculated using equation (2).

$$n = \chi_{0,05}{}^2[8] = \frac{\chi_{0,05}{}^2[8]}{2.0,03} = \frac{2,7326^2}{0.06} = 46$$

8. The acceptance plan is (46, 3).

The joints in every batch have been marked from 1 to 200. A generator of random numbers, which is a part of the QC Expert SW application, has been used for random selection of the sample of 46 items. Number of nonconforming joints has been 4 for adhesive number 1, 2 for adhesive number 2, 6 for adhesive number 3 and 4 for adhesive number 4.

The results are as follows: the joints made of adhesive 1 would be accepted, the joints made of other adhesives would be rejected. The lots of joints these adhesives could be subjected to the double or multiple sampling.

6. Conlusions

The method of acceptance sampling has been used for evaluation a workplace for adhesive assembly. The resistance of adhesive joints has been taken as a parameter for evaluation of joints quality. A single sampling method has been used, probability of acceptable fraction as well as non- acceptable fraction in the batch has been appointed in usual limits. The risk of the supplier and the risk of the customer have been appointed 5 %. The acceptance plan has been calculated. A random generator has been used for selection of random samples of every batch. The acceptable resistance of the joints has been appointed and the number of nonconforming joint in every sample has been found. The joints made of the adhesive number 1 have passed. The joints made of other adhesives have failed.

The reasons of this bad result can be either too hard criterion for acceptable joints or low quality of the joints.

References

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