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TESTING ACCELERATED LIFE DATA OF MICRO SWITCHES

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Abstract: The aim of this paper is to introduce a testing method for accelerated lifetime testing applicable for micro switches. To predict the lifetime the operating environment in the test device is designed to accelerate the switches' failure. The design of experiments is prepared with using the Taguchi method for different productions of micro switches applying different switching speed and different humidity values in the workbench.

Keywords: *Taguchi method, thermal camera, micro switches, accelerated life testing, switching cycle, orthogonal arrays*

1. INTRODUCTION

Our aim is to obtain reliable test results for determining the product's life cycle of micro switches widely used in garden tools. The requirement producing products with high reliability have increased the need for testing of systems, components and materials. Systems generally require system components having predetermined reliability during a determined time. It is difficult to assess reliability with traditional life tests recording only failure times. A relationship between component failure and operational conditions makes it possible to use accelerated models and to predict failure-time distribution.

Nowadays, the products are designed for years. In tests performed at normal conditions a few units will fail. Therefore, accelerated tests are widely used to obtain information on reliability of product components. In accelerated methods the main objective of these methods is to induce failures of the, units in a much shorter time and to use the failure data at the accelerated conditions (use rate, temperature or pressure) to estimate the reliability at normal operating conditions. There are several reliability models that correspond to physical-failure mechanisms [9]. These results are used to demonstrate the reliability of components, to certify the components or to compare components produced by different manufacturers.

The most common failures of micro switches have been considered in papers [4, 5]. The mathematical models applicable for analysing test results have been examined which can be used after collecting the results of the series of tests. Various test methods have been reviewed that can be used to estimate the expected life of products [6–8]. Here the initial steps in designing equipment to test structural elements is presented.

The test workbench has been planned and built. Testing the micro switch samples are implemented at the first prototype of the test workbench which is capable for testing four switches at the same time. Furthermore, we can follow the number of switches with the help of a PLC program. The aim of our research is to examine different types of switches according to a predefined method. During and after the measurements, we specify the operating conditions which provide a higher load than the normal load on the equipment. Our aim is to draw conclusions from the results of the measurements regarding the lifetime of the micro switches.

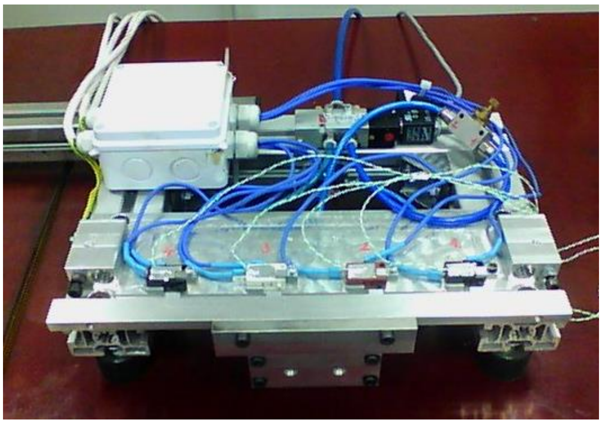

Figure 1. The test workbench

Taguchi's method will be used to design the experiments, which allows to create a well-designed measurement system. Here, the Taguchi method is introduced, and its applicability is examined on the base of previous articles [7–8]. How we can apply it to our experiments? Testing of micro switches would require multiple stress tests, results, which would mean running high number of tests. However, using the Taguchi method, the number of experiments that required, could be significantly reduced in this way.

2. DEVELOPMENT OF A METHODLOGICAL MEASURMENT SYSTEM BASED ON TAGUCHI METHOD

Taguchi, a Japanese engineer at Electrical Communication Laboratories, concluded that traditional tools for quality control and experiment design no longer met the demands of the modern age [1, 2]. Taguchi developed a new method for which he received a state award in 1960. In 1980 he introduced the experimental design in the Bell Laboratory, which has been known worldwide. Taguchi philosophy has revolutionized the industrial quality control method.

Table 1
Complete factorial experiment

	Name of the object						
	A	B	C	D	E	F	G
	Number of experiments	1	2	3	4	5	6
T-1	1	1	1	1	1	1	1
T-2	1	1	1	2	2	2	2
T-3	1	2	2	1	1	2	2
T-4	1	2	2	2	2	1	1
T-5	2	1	2	1	2	1	2
T-6	2	1	2	2	1	2	1
T-7	2	2	1	1	2	2	1
T-8	2	2	1	2	1	1	2

Three basic principles of this method are known [1–3]:

1. The quality of the product does not need to be retrospectively verified but it is designed into the product ("quality design").
2. The quality will be the best if we minimize the deviation from the target. The product must be designed to be insensitive to uncontrollable environmental influences ("robust design").
3. Depending on the deviation from the standard, the required "cost" of quality must be defined. Actual cost has to be regularly measured throughout the production process ("cost of quality").

The advantage of the Taguchi method is that it prefers practical and experimental design methods rather than mathematical formulas for experimental design. This method has been more successful than previous methods.

The previously applied method, the factorial experiment design method, helped the experimenter find the most important factors affecting the experimental result and all possible combinations of these. Their effect on the experimental result is important and also how to find the optimal combination of factors. However, these factorial designs become too complex in many cases and require extremely many experiments.

In the design of partial factorial experiments can still be well designed in terms of effect mixing due to missed interactions, but replication of eighth or even higher is already very difficult. By reducing the number of attempts to reach the optimum and increasing the number of factors and interactions that are relatively easy to examine, Taguchi has created experimental designs for some common tasks. He developed orthogonal tables for the experiment plans.

In these orthogonal tables ("orthogonal arrays"), Taguchi developed the most commonly known factor combinations and determined how to place the more important and less important effects and interactions in them. These tables are called Taguchi's "cookbook". The advantage of this cookbook is that the user does not have to think through all possible versions of all effects and interactions.

The experiment can be completed in three steps:

1. The characteristics of the quality, the main factors to be considered in the experiment and the possible value of their levels should be determined. In our case, these factors are switching speed and relative humidity. These values are recorded in *Table 2*.
2. Design and run the experiments according to a recipe in the Taguchi Cookbook.
3. Run a validation experiment under optimal conditions [1–3].

3. MEASUREMENST AND RESULTS

In our measurements that a total of four types of micro switches are tested, with two different switching speeds of 0.3 s and 0.25 s, with two relative humidity setting 60% and 80%. *Table 2* shows the failure cycles of the already ran switches.

Table 2
Database with failure result used Taguchi's method

Exp.No.	**Switch type**	**Switch speed [s]**	**Humidity [%]**	**Number of tests**			
				1	**2**	**3**	**4**
1	D.1	0.3	60	143,213	129,171	171,711	168,082
2	D.1	0.3	80				
3	D.1	0.25	60				
4	D.1	0.25	80				
5	D.2	0.3	60	180,230	191,019	182,428	196,031
6	D.2	0.3	80				
7	D.2	0.25	60	182,918	170,965	205,622	225,077
8	D.2	0.25	80				
9	K.1	0.3	60	189,966	197,341	197,917	201,465
10	K.1	0.3	80				
11	K.1	0.25	60	138,767	217,426	99,140	185,672
12	K.1	0.25	80				
13	K.2	0.3	60	180,235	212,592	209,829	209,829
14	K.2	0.3	80				
15	K.2	0.25	60	196,937	217,426	91,820	154,036
16	K.2	0.25	80				

The temperature distribution is measured during the tests. The horizontal axis in *Figure 2* represents the time of the test and the other axis show the temperature for a switch, as an example. The red curve indicates that the second micro switch sample's temperature suddenly rises to 133.8 °C, at this point it goes to failure. *Figure 2* presents the switch that showed the highest warm-up in the earlier stages of the test, it was not the fastest to break, but it is worked relatively moderately.

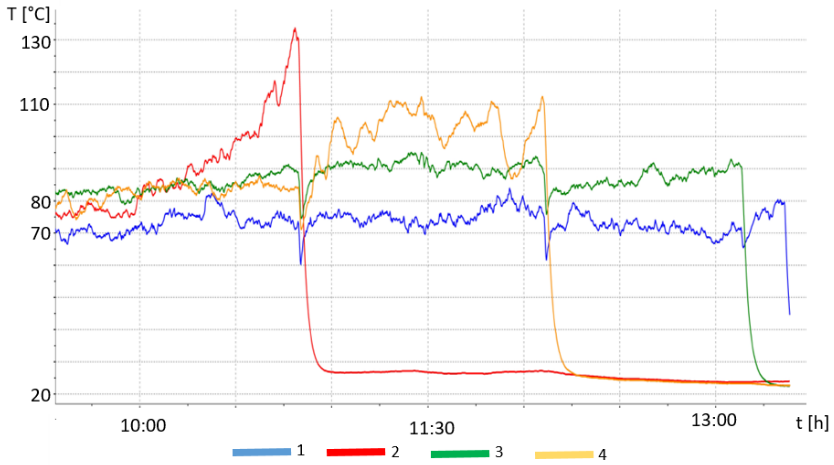

Figure 2. Temperature- time diagram

During the tests the heat impact are checked in several ways. Every switch has a temperature sensor and at the same time a special thermal camera is monitoring the temperature rise. The heat map shows that red areas are critical *(*see *Figures 3–4)*.

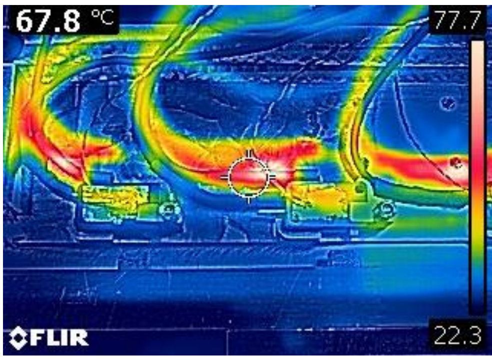

Figure 3. Photos taken by a thermal camera for two units

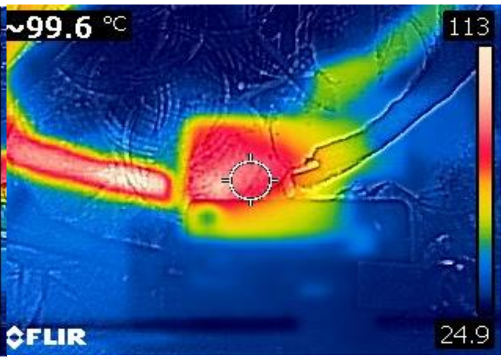

Figure 4. Photos taken by a thermal camera for one unit

The data logger records the test values in every 10 seconds, which is displayed on a spectacular temperature-time diagram. At the end of the measurements, the values recorded by the camera are the same as those have been measured by the temperature logger.

4. SUMMARY

In this paper a micro switch test workbench is introduced for measuring lifecycle of switches under accelerated operational conditions. The failure of the components of units is implemented according to measurement procedure based on the Taguchi method. The database *(Table 2)* with operation conditions data can be extended. Simulations can be performed for predicting lifetime data.

The tests are performed sequentially, by setting different statistical humidity levels. After completing appropriate number of tests, the test results can be used to develop a method that could be forecast the life expectancy of micro switches and make design and manufacturing recommendations that will influence the products lifetime.

Finally, a mathematical procedure that can validate the effect of several influencing factors on the life expectancy can be developed [9].

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