Design of Machines and Structures, Vol. 8, No. 1 (2018), pp. 29–35.

MICRO SWITCH FAILURE ANALYSIS

VIVIEN SIPKÁS–GABRIELLA BOGNÁR

University of Miskolc, Institute of Machine and Product Design
3515, Miskolc-Egyetemváros
machsv@uni-miskolc.hu

Abstract: The aim of this paper is to introduce the reliability methods in connection with lifetime, the moisture resistance test. Moreover, the way to the design of testing equipment using the method of design of experiment (DoE).

Keywords: *Accelerated Life Testing, Lifetime, Failure; Failure prediction; Reliability Prediction; Micro-switches; Acceleration Models*

1. INTRODUCTION

We shall understand the reliability that a product maintains its initial quality and performance at a certain period of time, cycle, distance etc. under given conditions without failure. These conditions include both environmental condition and operating condition. Environmental condition means a common natural ambience such as humidity, vibration, temperature and working condition means an artificial environment such as voltage, current load, place for installment and hours of use, which occurs during the life of the product [1].

It has already been stated in the previous article that the micro switches used in gardening machines unfortunately have several malfunctions [7]. Among others, due to the high temperatures, the deformation of internal components, the loss of function, switching and breaking of button switches can appear. In addition, the structure can be burned, and the contacting surfaces can be charred. For all these reasons, the switch will not work properly [7, 13].

The aim our investigations is to carry out pre-planned measurements and testing micro switches applied in garden tools. Therefore, we need an effective method for designing and analyzing experiments which allows objective conclusions to predict the lifetime of the examined switches.

2. ACCELERATED TESTS

Today's manufacturers face strong pressure to develop new products with higher technological content in record time while improving productivity, product field reliability and overall quality. This has motivated the development of such methods like concurrent engineering and has encouraged us to design experiments for product and process improvement. The requirements for higher reliability have increased the

need of testing the materials, the components and the systems. To achieve high reliability, it is necessary to improve the design and manufacturing processes.

In the literature we can find three different methods of accelerated reliability tests [11]:

2.1. Increase the use-rate of the product

Useful reliability information could be obtained in a matter of days instead of months.

2.2. Increase the aging-rate of the product

Increasing the level of experimental variables like temperature or humidity we can accelerate the chemical processes of certain failure mechanisms.

2.3. Increase the level of stress

In this last type we increase the level of stress, the temperature, the voltage, or the pressure during the tests comparing with the levels that units operate. A unit will fail when its strength drops below applied stress. Thus, a unit at a high stress will generally fail more rapidly than it would have failed at low stress.

Combination of these methods of acceleration are also employed. Variable like voltage and temperature cycling can both rate of an electrochemical reaction and increase stress relative to strength. In such situations, when the effect of an accelerating variable is complicated, there may not be enough, physical model for acceleration [11].

Combination of these methods are used in further stages of the research, because the micros witches will also be subjected to complex stresses.

3. ON THE PREDICTION METHODS OF RELIABILITY AND LIFE SPAN

The reliability prediction is to predict failure rate and average life span associated with reliability by taking operation, working environment and conditions associated with systems and parts into account. *(Figures 2–3)* refer to some types and measures of life span prediction. By conducting reliability prediction, manufacturers can predict product life span. Then, consumers can have a choice for product with longer life span. For components in the industry there are several prediction standards which allow us to predict failure rates of parts under a given system operation and working condition [3–6].

The *Figure 1* shows the lifetime prediction process that is primarily necessary to determine all the problems about the micro switches and their mechanism and physics of failure (see chapter 3.1. below). Simultaneously, it is necessary to test the lifetime of the micro switches. On the base of the flowchart, we are going to determine the acceleration models, – factors and then lifetime prediction.

The prediction will eventually be used mainly in design and product development stage of parts and system. Also, the prediction enables the operators to secure customer safety by building preventive maintenance plan in advance.

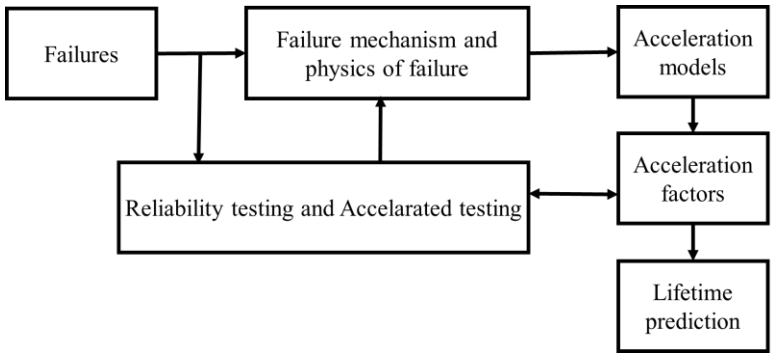

Figure 1. Lifetime prediction diagram [5]

Predicting the life span of parts and applying it to maintenance or conducting activities to promote longer life span by reflecting operation data feedback to a design are not yet a common practice and it is quite challenging.

Some examples are shown on the following figures *(Figures 2–3)*, these include the type of life span prediction and its method given is by manufacturers.

3.1. Life Span Prediction by using field data

We introduce some examples on life span prediction and its method on *Figure 2*, which represents it secured field data with quality that meets statistically needed information. This is a good example of the previously collected failures.

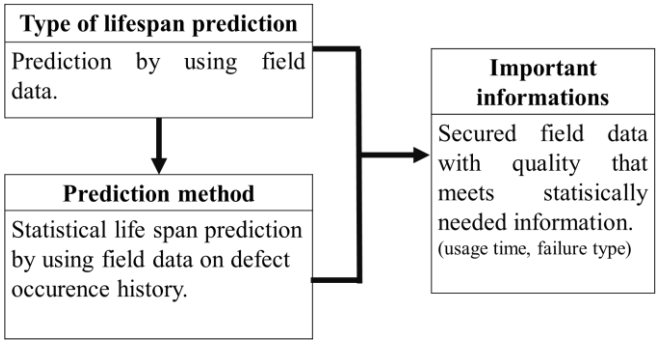

Figure 2. Lifetime prediction by operator as a prediction measure [1, 2]

Micro switches in garden tools may contain variety of faults, and our earlier publication has shown the most common types and the possible causes of their reasons [7, 13].

Typical failure problem is the wear of the micro switch's switch-button, which could be the result of poor construction design, high switching numbers etc.

Furthermore, deformation due to high temperature. There are several reasons for this problem, e.g., overheats due to overload and higher number of switching.

Burning of contacting surfaces is also very common breakdown, the cause of problems is higher humidity, – vibration of machine and etc. The result is there will be extensive burned signs on the contacting surfaces due to temperature increasing, surfaces will being sooted.

When the circuit is closed and interrupted, an arc is created. The material migration is the consequence of this phenomena, due to the heat generation and the increase of the temporary resistance. It results the overheating of the pre-assembled components such as springs [7]. These failure modes should be taking into account according to the method of *Figure 2*.

3.2. Life Span Prediction by conducting an accelerated life test

This lifetime evaluation can be adopted by manufactures to be considered at development stage [2].

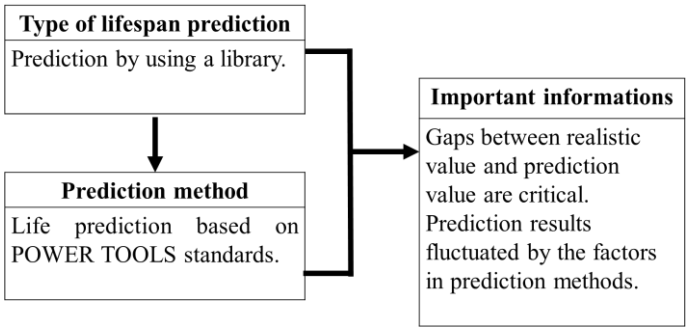

Figure 3. Life Span Prediction on the base of standards [1, 2]

Investigations can keep track of the research processes, which are often carried out according to appropriate standards. This is the IEC 60745-1 standard for handheld safety. Among the many chapters of the above standard, we apply the moisture resistance test, the essence of which is to place a given tool in the chamber and examine the temperature and humidity specified. Changing the temperature and humidity the micros witches operating the machines can have an operating effect. This test method is prescribed by the standard in an unladen condition. However, we would like to do it in a future laden state (e.g., switch operation) and not just a temperature and humidity range that is standard, but we want to do this by increasing both modes of use. As a first step, a standardized instruction is required and a test of an unladen condition has to be performed.

The humidity treatment carried out in a humidity cabinet containing air with a relative humidity of (90–100%) and room temperature is required. Before inserting into the air humidity chamber, the tool must be brought to a specified temperature, which is approximately a few degrees Celsius to approximately the operating state of a machine. Then we will be in the cabinet within the prescribed time limit for a specified period.

In order to achieve the specified conditions within the cabinet, it is necessary to ensure constant circulation of the air within and, in general, to use a cabinet which is thermally insulated [8].

4. DESIGN OF EXPERIMENTS

The term experiment is defined as the systematic procedure carried out under controlled conditions in order to discover an unknown effect, to test or establish a hypothesis, or to illustrate a known effect. When analyzing a process, experiments are often used to evaluate which process inputs have a significant impact on the process output, and what the target level of those inputs should be to achieve a desired result. Design of Experiments can be designed in many different ways to collect this information is an effective method for designing and analyzing experiments so that the data obtained allows for the deduction of real and objective conclusions. This method is a detailed experiment plan with settings and order that must be available before the experiment is completed.

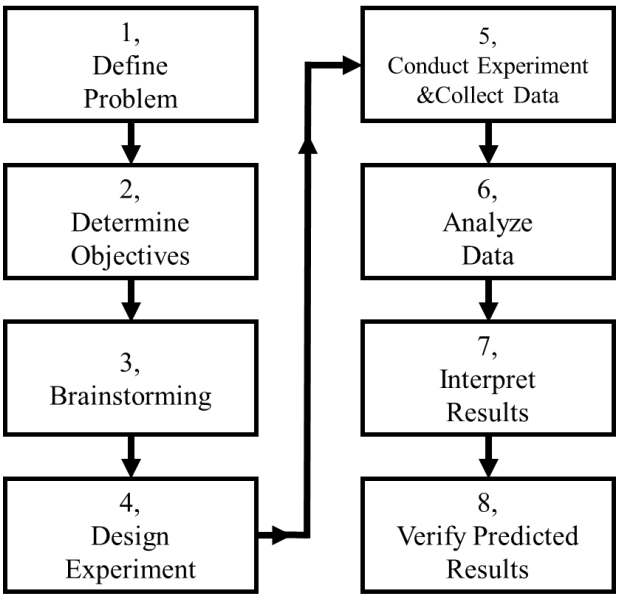

Figure 4. Design of Experiments Process [9]

Using the Design of Experiment method, we have already defined the problem that the micro switches used in gardening machines are far below the manufacturer's required edge. There are more failures than the waited.

Thus, we have to define the goal of constructing an equipment that can provide complex data set for more products. After the first two points have been defined, the process of thinking about the features of the device is taking place *(Figure 4)*.

Designed experiments give the possibility of advanced and powerful analysis. An effective experimentation method can filter disturbing factors and discover significant process factors. The factors then can be used to control further testing. Well-designed experiments not only save time but also solve critical issues that are not yet visible in processes. Specifically, the interaction of factors can be observed and evaluated. Ultimately, we can find out which factors, results are counted, and whose life-span influences [9, 10].

5. CONCLUSION

In this paper the most important type of accelerated test methods, the prediction method of reliability and life span are considered. Two of these methods were introduced based on literature, which can be used in closely in the investigation of micro switches. By reviewing standards, we summarized that the most important steps of the moisture resistance test, which will be carried out in the further stages of the research, first according to the standards, and then with certain modifications at different higher temperature ranges, thereby increasing the load. After that, we considered the Design of Experiment method, which is an effective method for designing and analyzing and evaluating experiments.

ACKNOWLEDGMENTS


„ Supported BY the ÚNKP-18-3-I-ME/19. New National Excellence Program of the Ministry of Human Capacities”

REFERENCES

[1] Jung-Geon Ji, Kun-Young Shin, Duk-Gyu Lee, Moon-Shuk Song & Hi Sung Lee (2012). Life Analysis and Reliability Prediction of Micro-Switches based on Life Prediction Method. *International Journal of Railway*, Vol 5, No. 1, March 2012, 1–9.

[2] Shin, K. Y., Ji, J. G, Han, J. H, Lee, D. G, Son, Y. J. & Lee, H. S. (2011). *Life analysis and reliability prediction of relays based on life prediction method*. Spring Conference of Korean Society for Railway.

[3] Reliability in electronic. Technical article. *The expert in power*, 1–11. www.xppower.com, 2018. 10. 15.

[4] P. Bardos (1979). *Reliability in Electronics Production*. Proceeding of PCIM, Munich.

[5] A. L. Hartzell et al. (2011). *MEMS Reliability, MEMS Reference Shelf, Lifetime Prediction*. DOI 10.1007/978-1-4419-6018-4_2, Springer Science + Business Media, LLC 2011, pp. 9–42.

[6] European Power Supply Manufacturers Association (2005). *Guidelines to Understanding Reliability Prediction*. Edition 24 June 2005. www.epsma.org

[7] Vivien Sipkás & Gabriella Bognár (2018). The Application of Accelerated Life Testing Method for Micro Switches. *International Journal of Instrumentation and Measurement*, pp. 1–5.

[8] *General requirement for garden tools*. IEC 60745-1 Ed 4 2006-04

[9] https://www.moresteam.com/toolbox/design-of-experiments.cfm, Date of download: 17. 10. 2018.

[10] Márkus László (2018). Az ipari kísérlettervezés statisztikai módszerei. Educational supplement, date of download: 17. 10. 2018.

[11] William Q. Meeker & Luis A. Escobar (1998). Statistical Methods for Reliability Data, Wiley-Interscience Publication–John Wiley& Sons.

[12] Sipkás Vivien & Vadászné Bognár Gabriella (2017). Mikrokapcsolók gyorsított élettartam vizsgálata. *GÉP*, Gépipari Tudományos Egyesület Műszaki Folyóirata, 2017/4. LVXXIII. évfolyam, pp. 57–60. (in Hungarian)

[13] Sipkás Vivien & Vadászné Bognár Gabriella (2017). Mikrokapcsolók élettartamának vizsgálata. *Jelenkori társadalmi és gazdasági folyamatok*, 12, pp. 95–102. (in Hungarian)