Abstract: This paper presents research about accelerated life data and a simulation of a case study using Monte Carlo method. The statistical processing was realized using the ALTA 7 software. The main objective of this study is to determine the indicators of reliability (Probability density function, Reliability function, Unreliability function, Mean time to failure, Failure rate, and acceleration factor) in normal use for the case study analyzed. The case study is represented by a set of data from accelerated tests with two stresses. Using the previously determined parameters and the accelerated levels, we simulated with the help of ALTA 7 software the values for the times to failure in accelerated conditions. Key words: reliability, ALT, accelerated model, Monte Carlo simulation,

1. INTRODUCTION

Although the technological achievements of the last 50 years can hardly be disputed, there is one weakness in all mankind's devices. That is the possibility of failure. What person has not experienced the frustration of an automobile that fails to start or a malfunction of a household appliance. The introduction of every new device must be accompanied by provision for maintenance, repair parts, and protection against failure. This is certainly apparent to the military, where the lifecycle maintenance costs of systems far exceed the original purchase costs. The problem pervades modern society, from the homeowner who faces the annoyances of appliance failures, to electric utility companies faced with the potentially disastrous consequences of nuclear reactor failures. The insurance industry would not exist without the possibility of one type of failure or another. A subject that is so important to many decisions in this world could hardly escape quantitative analysis. The name reliability is given to the field of study that attempts to assign numbers to the propensity of systems to fail. In a more restrictive sense, the term reliability is defined to be the probability that a system performs its mission successfully. Because the mission is often specified in terms of time, reliability is often defined as the probability that a system will operate satisfactorily for a given period of time. Thus reliability may be a function of time. Estimating reliability is essentially a problem in probability modeling. A system consists of a number of components. In the simplest case, each component has two states, operating or failed. When the set of operating components and the set of failed components is specified, it is possible to discern the status of the system. The problem is to compute the probability that the system is operating - the reliability of the system [1].

Products are ‘born’ in the sense that they are manufactured. They enjoy some period of useful service and ultimately ‘die’ when their service comes to an end, typically by one of the following: product failure, retirement, replacement, or disposal. Also known as life cycle, service life, or useful life, life is defined as the quantity that most
accurately represents how long a product or system lasts. Service life may be defined in terms of total calendar time since fielding, or may be defined exclusively in terms of use-hours (such as flight-hours for aircraft). In some cases, life may even be measured strictly in terms of usage (such as the total mileage on a car), and not on any time measurement. What varies by each case is what constitutes the end of life. At the material and component levels, many of these items are allowed to serve in their capacity until they fail to work, at which time they are usually replaced, either with an identical article or an upgrade. However, high-criticality materials or components are not allowed to run until failure for reasons of safety. Assembly level constituents or higher are usually considered critical, and thus are not allowed to operate until failure either. Instead, they are operated for a fixed interval of time before they are serviced or replaced. Beyond reasons of safety, the service lives of non-critical elements are fixed because their service or replacement follows a set schedule for reasons of economics or convenience [2].

2. REVIEW OF ALT TECHNOLOGY

Many of the industrial products produced today for complex technical systems have very high reliability under normal use conditions. The questions then arise of how to make the optimal choice between several types or designs of a device and how to collect information about the corresponding life distributions under normal use conditions. A common way of tackling these problems is to expose the products to sufficient overstress to bring the mean time to failure down to an acceptable level. Thereafter, one tries to "extrapolate" from the information obtained under over stress to normal use conditions. This approach is called Accelerated Life Testing (ALT) or overstress testing. In these tests, reliability practitioners may force the product to fail more quickly than it would under normal use conditions [3].

The basic propose of ALT is to obtain initial information for issues of quality, reliability, maintainability, supportability, and availability. It is not the final goal. It is accomplished through prediction using the information provided by ALT under laboratory conditions. The most effective ALT of a product design needs to occur under natural (field) conditions. ALT design and the selection of appropriate testing parameters, equipment, and facilities for each method or type of equipment to be tested must be coordinated to provide the test inputs and results that are most beneficial for the quality, reliability, or maintainability problems that the test identifies.

The primary purpose of an ALT is to estimate the life distribution and quantities of interest at a use condition. This estimation involves extrapolation from higher stress levels by using an acceleration model, and thus includes the model error and statistical uncertainty. Sometimes, the model error outweighs the statistical one. The model error may be reduced or eliminated only by better understanding the failure mechanisms and using a more accurate model, whereas the statistical uncertainty can be reduced by carefully selecting a good test plan. A typical test plan is characterized by the stress levels, the number of test units allocated to each level, and their censoring times. The most commonly used ALT in modern manufacturing industry is the constant-stress ALT where stress applied to a sample of units is constant. A typical parametric model of ALT consists of two components: (1) a lifetime distribution that models the time-to-failure at a constant-stress level; and (2) a stress-life model that quantifies the manner in which the lifetime distribution changes across different stress levels. There are different types of ALT plans in use, which include subjective, traditional, best traditional, and statistically optimum and compromise plans [4].
In general, the accelerated life testing can be divided into two categories: qualitative ALT and quantitative ALT. Qualitative ALT, such as Highly Accelerated Life Testing (HALT), Highly Accelerated Stress Screening (HASS), torture tests, shake and bake tests, are used primarily to reveal probable failure modes for the product so that product engineers can improve the product design. Quantitative ALT consists of tests designed to quantify the life characteristics of the product, component or system under normal use conditions and thereby provide reliability information [5].

Pursuing the previously stated main purpose of the accelerated life tests, we need a model that relates life to accelerating stress, such as temperature, humidity, and voltage. Such models, usually called acceleration models, can be classified into the following three types: physical models; quasi-physical models; empirical models. Among the most important acceleration models (life-stress) we can mention the following: Arrhenius, Eyring, Inverse Power Law; Life - Thermal Cycling, Life - Voltage, Life - Vibration, Life - Humidity, Life - Temperature – Humidity.

Three basic approaches use ALT technology as shown in figure 1.

Fig. 1. Three basis direction of ALT

The first approach is special testing with more intensive usage than under a normal use. The second approach is to use accelerated stress testing (AST). For example, if one conducts research upon or tests the actual car using a simulation of the field input influences with special equipment, then the level of car (or other product) loading is higher than it is normal usage. The third approach relies on using a computer (software) simulation or analytical/statistical methods. Computer simulations have become a useful part of the mathematical modeling of many natural systems in physics and engineering.

3. CASE STUDY

Monte Carlo simulation is a powerful tool for modeling: the reliability data of industrial products; the behaviour of some activity, plan or process that involves uncertainty. If you face uncertain or variable market demand, fluctuating costs, variation in a manufacturing you can benefit from using Monte Carlo simulation to understand the impact of uncertainty, and develop plans to mitigate or otherwise cope with risk. Its core idea is to use random samples of parameters or inputs to explore the behaviour of a complex product or process.

In many cases, the life of a product is a function of stress and some other engineering variable, like materials, vendors or operation type. For this type of product, ALTA 7 provides the general log-linear life-stress relationship, which allows you to analyze up to eight stress types and specify an underlying relationship for each stress. ReliaSoft's ALTA 7 software provides an extensive array of tools to help you understand and communicate how a product will perform over time.

A sample with 25 electronic components is subjected to a quantitative accelerated life test in which two stress types are applied to the units. The stress types include temperature and voltage. The time-to-failure data are presented in Table 1. The normal use stress levels are 300 K for temperature and 12 Hz for vibration. The general log-linear life-stress model is used and the Weibull distribution is used as the underlying life distribution for the data set.
Poor accelerated life test plans waste time, effort and money and may not even yield the desired information. Before starting an accelerated life test, it is advisable to have a plan that helps in accurately estimating reliability at operating conditions while minimizing test time and costs. To design the plan for the accelerated life tests of the specimen made out of supple platinum it is necessary to establish the following parameters:

- the acceleration model: temperature – non-thermal (T-NT) model;
- the number of components subjected to accelerated life tests: for accelerated life testing we used 25;
- the distribution law of times to failure used in accelerated life testing: the Weibull distribution was chosen to test the components;
- the stress under normal condition and in accelerated condition: the temperature and vibration in normal testing conditions is 300 K, 12 Hz and the maximum temperature and vibration is 350 K and 18 Hz;
- the accelerated life test plan: for the accelerated life testing of the electronic components we chose 3 levels optimum plan. The test plan was realized using the ALTA software (figure 2).

The ALTA 7 software generates an optimum testing report, where the levels of accelerated life testing and the number of components tested at every accelerated stress level are specified. The testing parameters resulted from the design of the accelerated life testing plan for the specimens made from supple platinum are as follows: 3 levels of testing: 300 K – 15 Hz, 325 K – 12 Hz, 350 K – 18 Hz; the number of tested specimens corresponding to the level of acceleration: 10, 9 and 6 components.

The Monte Carlo simulation window with censoring after a specific number of failures (25) is described in figure 3.

![Fig. 2. Design of experiment of ALT](image)

![Fig. 3. Monte Carlo simulation](image)

Failure times resulting from Monte Carlo simulation method are described in figure 4.

![Fig. 4. Time failed vs. Stress 1-2](image)
In figure 5 is described the reliability function (2D) in normal condition (300 K and 12 Hz) for the electronic components.

**Fig. 5. Reliability function – 2D plot**

In figure 6 is represented the reliability function (plot 3D) in normal condition (300 K and 12 Hz) for the electronic components.

**Fig. 6. Reliability function – 3D plot**

PDF - a mathematical model that describes the probability of events occurring over time. This function is integrated to obtain the probability that the event time takes a value in a given time interval. In life data analysis, the event in question is a failure, and the pdf (figure 7) is the basis for other important reliability functions, including the reliability function, the failure rate function and the mean life.

**Fig. 7. Probability density function (pdf) – 3D plot**

Using the QCP, the mean life at normal pressure (300 K and 12 Hz) is estimated to be 2962 hours as shown in figure 8. The mean life function, such as the mean time to failure (MTTF), is widely used as the measurement of a product's reliability and performance. This value is often calculated by dividing the total operating time of the units tested by the total number of failures encountered. The case study analyzed in this paper, the mean life is determined taking into account only the time of failure (without censored units).

**Fig. 8. Mean life at normal stress**

BX life represents a time period during which a certain proportion of the population will fail. For example, the B10 life is the time in which 10% of the population will fail. In figure 9 was determined B10 indicator for the case study analyzed in this paper.
4. CONCLUSION

At some industrial products (from the aviation, nuclear and electronic fields), for which a high reliability is estimated, the determination of the life time and of the reliability parameters, under normal stress conditions, implies a long testing period. For this reason we opted for the accelerated life testing methods. These are tests being performed at more intense stress conditions, compared to the normal stress conditions, with the purpose of intensifying the degradation processes and, as an economic result, the shortening of the period and costs related to the testing, while preserving the same failure modes and mechanisms. Accelerated testing is an interdisciplinary field covering topics such as aging characteristics of materials, degradation mechanisms, testing, reliability, statistics, and life assessment. This article provides a case study with two stresses into the field of accelerated testing. Accelerated testing can prove to be a valuable tool for a variety of applications including reliability and life prediction, materials and manufacturing processes selection, and quality control. As further research I will expand the accelerated tests on other components from engineering products using three or more stresses.

5. ACKNOWLEDGEMENT

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the project number POSDRU/89/1.5/S/59323.

6. REFERENCES


7. DATA ABOUT AUTHORS

Postdoctoral student ZAHARIA Sebastian Marian, Transilvania University of Brasov, Technological Engineering and Industrial Management, Address: Colina Universitatii nr. 1, Brasov, Romania.
Phone: +40-(268) 41.46.90.
Email: zabaria_sebastian@unitbv.ro;

Prof. MARTINESCU Ionel Ph.D., Transilvania University of Brasov, Technological Engineering and Industrial Management, Address: Colina Universitatii nr. 1, Brasov, Romania.
Phone number: +40-(268) 41.46.90.
Email: ionel_martinescu@unitbv.ro;

Asoc. prof. MORARIU Cristin Olimpiu, Transilvania University of Brasov, Technological Engineering and Industrial Management, Address: Colina Universitatii nr. 1, Brasov, Romania.
Phone number: +40-(268) 41.46.90.
Email: c.morariu@unitbv.ro.