

Aspects of using accelerated weather testing methods for polymeric materials

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Abstract. The paper investigates the aspects of using accelerated weather testing methods for polymeric materials. The need has been identified for consistency of polymer ageing and degradation mechanisms in full-scale and laboratory conditions, as well as for equipment that most closely simulates the actual operating conditions.

1. Introduction

The properties of different polymeric materials change (ageing) as they are used in machine production, construction, electrical and radio engineering, agricultural sector. Ageing of a material during the operation and storage is a result of a series of chemical and physical transformations in complex multicomponent systems [1].

The properties of basically all polymeric materials have low time-dependent stability. Under the influence of heat, oxygen, air, light, mechanical stresses, ionizing radiation and other factors polymeric materials degrade: there are processes running in them, which are accompanied by change in their chemical and physical structure and deterioration of their strength, dielectric and other properties [2].

The factors contributing to ageing can be divided into two main categories: internal (inner stresses, phase transitions, microstructure transformations, changes in chemical composition) and external (change in temperature, humidity, oxygen concentration, visible, ultraviolet (UV) or ionizing radiation, chemical exposure) [3, 9-10].

Ageing of a material can manifest itself in various forms. The form depends not only on the properties and composition of the material but also on the type of influence. The external factors can be divided into six types of ageing which can be combined with each other: thermal ageing; weathering; attack by corrosion and chemical ageing; strain ageing; electrical ageing; UV ageing [3].

2. Body text

There are hundreds of brands of polymeric materials based on synthetic resins, rubbers and high-molecular compounds. They are used in all the manufacturing and construction sectors. Thus far, a lot of research has been done to design new polymer compositions and lower their cost, simplify the production methods, reduce production toxicity, as well as provide a wide operating temperature range. Due to a large number of basic components the properties of resulted polymers can be highly varied. Polymers are widely used in the vehicle industry: noise and thermal insulation, exterior and interior parts, fuel system components [4 - 6].



Today the polymeric material durability and service life prediction remain understudied. The service life of polymer products can vary from 2-3 to 10 years or more depending on their purpose, operating conditions, technical and commercial requirements. However, process designers of polymeric materials have no universal tools to design these materials with the required durability.

In development of new products and scientific research artificial ageing is used. It is a process of simulating the influences on a material to reproduce its ageing process. It may require climatic chambers, environmental simulation equipment and vibration testing systems. It is important to monitor and record any changes in the material properties during development. All the results should be repeatable to help engineers investigate the probability of material degradation [3].

Accelerated weather testing methods are based on transformation of energy values of the operational factors (related to ageing and degradation of materials and products) to the suitable laboratory conditions of accelerated testing. The algorithm of development of accelerated weather testing methods include the following stages: development of an operation chart; transformation of energy values of the operation factors to enhanced simulated laboratory factors; development of laboratory conditions of accelerated weather testing. The main criteria of accelerated weather testing are as follows: maximum reduction of testing time; consistency of the ageing mechanisms in full-scale and accelerated laboratory conditions [2].

We are going to examine the aspects of using accelerated weather testing methods in real life. The claims were found for operation of polypropylene components used in the engine cooling systems in different climatic operation zones between 2013 and 2016 (Figure 1, 2).

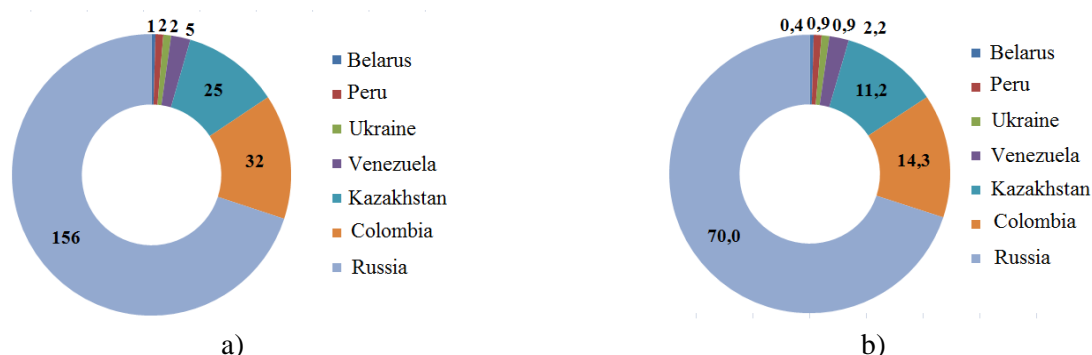


Figure 1. Breakdown of the claims for replacement of polypropylene products by climatic zones: a) in units; b) as a percentage

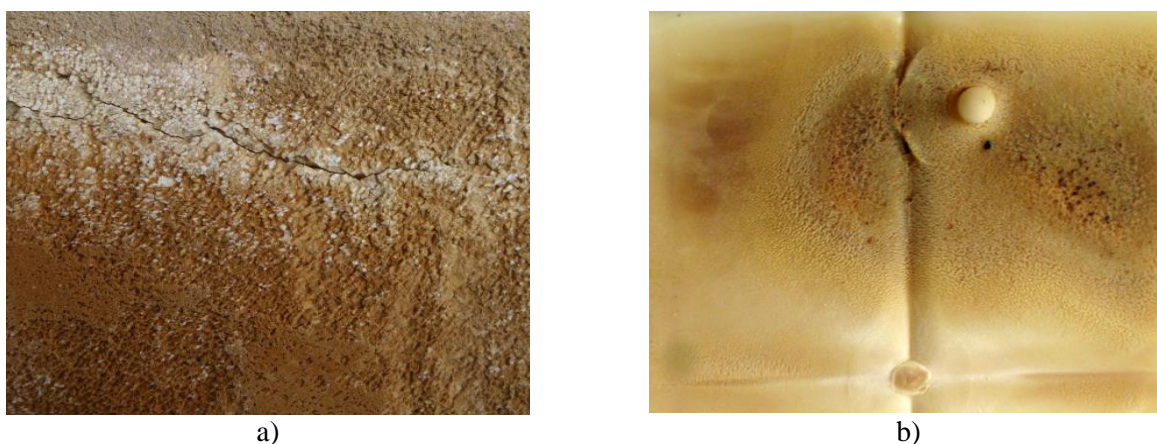


Figure 2. Visual appearance of damage in polypropylene components as the result of influence of: a) climatic factors; b) accelerated weather testing

Accelerated weather tests were performed to determine the factors contributing to ageing. For this purpose, the experimental setup with an UV radiation source (1000 W tubular mercury vapour lamp) was used [7]. The operation chart was developed according to GOST 16350-80, Climate of the USSR. Regionalizing and statistical parameters of climatic factors for technical purposes [8]. As the main portion of product claims was found in southern Russia the climatic zone II10 "Warm humid Batumi" was applied. Energy values of the operational factors were calculated into enhanced simulated laboratory factors, the laboratory conditions of accelerated weather testing were developed. 1 year of real-life conditions is equivalent to 29 hours of accelerated weather testing. Figure 2 shows the investigation results.

Figure 2 reveals the significant difference in visual appearance of the defects. When transforming the energy values of the operational factors into enhanced simulated laboratory conditions the polymer ageing and degradation mechanisms under full-scale and laboratory conditions were thought to be different due to different rates of relaxation processes, different rates of competing processes, different synergistic effect. In addition, the activation spectrum initiated by the tubular mercury vapour lamp does not match the real-life spectra. Xenon arc lamps with a Pyrex glass filter should be used to simulate UV radiation. The severe conditions of accelerated weather testing initiated the mechanism of material degradation due to thermal decomposition. In the real-life operating conditions products are simultaneously subjected to different types of ageing: thermal ageing, UV radiation, mechanical stress and attack by corrosion [1, 2].

3. Conclusions

LFI technology helps to increase the production flexibility and quality, reduce the production cost of products, especially large-sized ones, thanks to a high quality of manufacturing and a lower amount of production waste.

This work was supported by the research grant of Kazan Federal University.

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