IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 8, August 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

Forecasting Operability of Polymer Composite Materials

Vyacheslav Trachevskiy[1,3], Mykola Kartel[2,3], Yurii Sementsov[2,3] and Wang Bo[3]

[1]National Aviation University, Kyiv, Ukraine,

[2]O. Chuiko Institute of Surface Chemistry, NASU, Kyiv, Ukraine,

[3]Ningbo University of Technology, Ningbo, China

Abstract

On the basis of experimental data, the possibility of investigating the processes of accelerated ageing is shown to predict the operability and storage times of polymer compositions for the structural elements of aeronautical techniques for changing the constants of thermogravimetric analysis of the corresponding polymer compositions.

Keywords: *Polymer Composites, Ageing, Stability of Properties.*

1. Introduction

To determine the feasibility of using promising polymer composite materials as elements of aviation equipment, it is necessary to know the real terms of their reliable operation and storage, taking into account operational requirements. Only long-term full-scale tests give reliable results in evaluating the ageing of polymer composite materials, but they are often obsolete by the time of their production.

One of the ways to reduce the duration of the study of ageing of polymer compositions is to intensify the effect of climatic factors and to create accelerated laboratory techniques simulating various climatic conditions [1, 2].

For scientifically based accelerated studies, it is necessary to quantitatively estimate the correlation interrelation between the influence of climatic factors on the change in the physicochemical and, therefore, the performance characteristics of the polymer composite material.

Despite the abundance of various factors that reduce the longevity and efficiency of polymer elements of aviation equipment, the influence is exerted on polymer composite materials of radiation, temperature and oxygen [3, 4].
Chemical transformations in polymers under aging are reduced, basically, to two processes: the structuring and destruction of macromolecules of the material. As a result of the first process, individual polymer chains are cross-linked leading to the formation of spatial three-dimensional structures, which entails an increase in the strength of the polymeric composite material, but the polymer composite material itself becomes rigid, brittle, and loses its elasticity, Leads to the loss of the required performance characteristics. The second process - destruction - leads to the rupture of molecular chains and a decrease in the molecular weight of the polymer, as a result of which the polymer composite material becomes soft, sticky and loses its mechanical strength and, therefore, the required performance characteristics. Therefore, the main problem of the stability of a polymeric composite material to ageing should be estimated from the change in the chemical structure under the influence of ambient conditions (ionizing radiation, temperature, oxygen).

2. Materials and Methods

In the present work, a polymer composition consisting of a urethane former (SCU-PFL) and a polyisocyanate (TT-75) with the ratio NCO/OH = 1.25 was taken as the object of the study. As an additional cross-linking compound, phenyltributylglycosisilane (PBS) was introduced into the polymer composition.

As a criterion for assessing the change in the chemical structure, the effective activation energy (E_A) of the thermooxidative degradation of the polymer composition determined by thermogravimetric characteristics was chosen.

Thermogravimetric characteristics were determined during dynamic thermogravimetric analysis (DTG) together with differential thermal analysis (DTA) on a Derivatograph of the Paulik-Paulik-Erdey system in air at a rate of temperature rise of 2.5...5°C/min in the temperature range 100...600°C. Calculation of kinetic

parameters of thermooxidative degradation was carried out according to the developed technique.

The efficiency of the polymer composite material was determined by the change in the three-biological parameters determined by the required performance characteristics in harsh climatic conditions.

3. Results and Discussion

To confirm the choice made, a study was made of the effect of the cross-linkable PBS compound, which makes it possible to purposefully change the structure of the polymeric composite material to thermooxidative destruction of the composition by changing the effective activation energy (Fig.1).

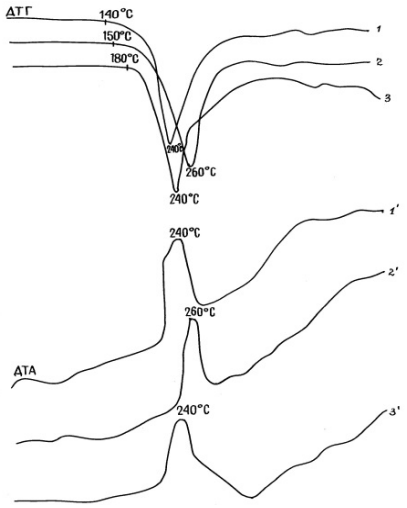

Fig. 1 Thermogravimetric curves of PU compositions with different PBS content:
1,1´ – 0%; 2,2´ – 10%; 3,3´ – 15%.

As can be seen from the figure, the introduction of the PBS additive changes the form of the thermogravimetric curves and temperature peaks, which indicates a change in the structure of the polyurethane composition, and, consequently, the change in the effective activation energy of the thermooxidative destruction.

A study of the physico-mechanical properties of PU showed that the introduction of PBS into the composition promotes the production of films with higher strength properties.

Table 1: Physico-mechanical properties of PU modified by PBS

№ п/п	Additive content, %	Deformation, (E), %	Tension, (σ), MPa	Gel Fraction, %
1	0	20	46.8	73.8
2	5	25	60.2	79.0
3	10	35	68.0	98.5
4	15	30	58.7	98.0
5	20	30	57.5	96.7
6	30	28	50.7	79.5
7	40	21	45.0	70.5

As the PBS content increases, the rigidity of the system, its hardness and tensile strength increase, and the value of the effective energy of PU destruction processes increases. The best complex of properties is the composition modified by 10% PSB. Introduction in the polyurethane composition of PBS in an amount of 20% and 30% significantly increases the rigidity of the system, reduces the scope.

The physical and mechanical properties of the polyurethane compositions of modified PBS vary depending on the amount of additive added and are given in Table 1.

In addition, and most importantly, the introduction of a cross-linking compound affects both the structure of the composition formed and the operability of the polymer elements of aviation equipment. The experimental results obtained are presented in Table 2.

Table 2: Dependence of the activation energy of the SKU-100 composition and its operability on the content of the cross-linking compound

The content of the cross-linking compound, %	Hardness, rel. un.	E_A, kJ/mol	Performance, cycle
0	0.40	165.7	15
5	0.55	215.6	1000
10	0.73	246.9	1500
15	0.70	256.0	1500

It can be seen from the Table 2 that a change in the physico-chemical properties of the polymer composition when a cross-linking compound is introduced leads to a change in the effective activation energy of the thermal-oxidative degradation of the composition.

In addition, there is a change in the working capacity of the polymer composite material under difficult climatic conditions, and there is a definite value of the activation energy, below which a sharp decrease in the operability of the polymer composition and deterioration of its

physicochemical properties begins. Therefore, it was of interest to determine the possibility of using derivational analysis to predict the longevity or lifetime of polymer compositions based on the determination of the change in the value of the activation energy during the degradation of the polymer composition under accelerated aging (radiation, heating) and extrapolation of the reaction rate or time and the actual ageing conditions.

Table 3: Effects of irradiation on the operability and activation energy of the polymer composition

The dose of irradiation, Gr	E_A, kJ/mol	Performance, cycle
0	247.0	1500
50	229.7	1500
100	185.7	1000
250	105.4	< 10

Previous studies have shown that the effect of ionizing radiation on polymer composite materials causes a change in their physico-chemical properties and, consequently, performance in difficult climatic conditions. Therefore, it was of interest to investigate the change in activation energy, the thermooxidative destruction of a polymer composition when it is irradiated with ionizing radiation (Co^{60} γ-irradiation). Table 3 shows the experimental results.

As can be seen, the effect of ionizing radiation, leading to an accelerated ageing of the polymer composition, causes its structural changes, which leads to a decrease in the activation energy of thermal-oxidative degradation.

Thus, the obtained results show the possibility of studying the processes of accelerated ageing for predicting the operability and storage times of the polymer composite elements of aviation equipment by changing the effective activation energy of the thermal-oxidative degradation of the corresponding polymer composite materials.

Table 4 shows the results of studying the change in the activation energy of thermal-oxidative degradation during accelerated aging of the polymer composition.

Table 4: Changes in the activation energy of degradation of polymer compositions with accelerated ageing

Composition	Image state	E_A, kJ/mol	Performance, cycle
SKU-BDM	Initial	148.1	1000
	500 Gr	68.0	< 10
SKU-PFL-100	Initial	189.8	1500
	500 Gr	134.4	Glue-like
SKU-PFL-3	Initial	186.9	1500
	500 Gr	169.9	1500

As you can see from the results of Table 4 the value of the activation energy decreases with accelerated ageing, and for different polymeric materials in various degrees. Therefore, the results obtained make it possible to predict the real lifetimes of polymer compositions as elements of aviation equipment with respect to the previously determined activation energy for known polymer compositions. Thus, the developed method can be used to compare the timing of maintaining the performance characteristics of polymer compositions, for which it is necessary to establish a correlation between accelerated and natural aging processes.

In addition, analyzing the results obtained, it can be concluded that the dye-vitro analysis allows us to identify the elements of aircraft engineering by the composition of the polymer composition and to predict the performance characteristics of the polymer composition of one formulation, There is a clear correlation between the results of the evaluation of the operability of the polymer composition and the values of its activation energy of thermal-oxidative degradation. At the same time, the results of these studies are confirmed by the results of full-scale tests of aviation equipment elements.

4. Conclusions

The interrelation between the operability and storage time of polymeric composite materials and the change in the constants of derivational analysis has been established.

By changing the effective activation energy of thermooxidative degradation of polymer compositions under accelerated ageing, it is possible to predict the timing of the maintenance characteristics of the relevant aircraft.

References

[1] Pavlov N.N. *Starenie plastmass v estestvennykh i iskusstvennykh usloviyakh (Aging of plastics under natural and artificial conditions)*, Moscow: Khimiya, 1982, 224 p. *(in Russian).*

[2] Ivanov S.V., Trachevskii V.V., Titova O.S., and Zozulya L.A. Prognostication of aging of polymeric composite materials, *Russian Journal of Applied Chemistry*, 2006, Vol. 79, No. 10, pp. 1712-1714.

[3] Ermak A.A., Tkachev S.M., Khoroshko S.I. et al. Method of predicting the properties of compounded asphalts, *Chemistry and Technology of Fuels and Oils*, 2005, Vol. 41, No. 6, pp. 486–490.

[4] Bystritskaya E.V., Karpuzin O.N., and Kryuchkov A.A. Thermogravimetric analysis as applied to prediction of plasticizer desorption from flexible poly (vinyl chloride) compounds, *Polymer Science Series B*, 2006, Vol. 48, No. 1, pp. 46–50.

Vyacheslav Trachevskiy, PhD (Chem.), Associate Prof. of the National Aviation University in Kiev. He is an expert in the field polymer materials, composite materials, methods of their preparation and testing.

Mykola Kartel, Dr. Sci. (Chem.), Prof., Academician, Director of the Chuiko Institute of Surface Chemistry of the National Academy of Sciences of Ukraine. The head of the several researches in the field of physical chemistry, in particular, surface chemistry and physics, which are carrying out in the National Academy of Sciences of Ukraine.

Yurii Sementsov, PhD (Phys. & Math.), Senior Researcher of Physics and Chemistry of Surfaces, Senior Researcher of the Department of Physical Chemistry of Nanoporous and Nanoscale Carbon Materials of the Chuiko Institute of Surface Chemistry of the National Academy of Sciences of Ukraine. He is an expert in the field of nanosized carbon materials with a graphite-like structure and head of the Project from Ukrainian side.

Wang Bo, Assoc. Prof., PhD (Econ.), Director of China-Central and Eastern Europe International Science and Technology Achievement Transfer Center of Ningbo University of Technology, Ningbo, China.