INDUSTRIAL SECTION

STRENGTH AND THERMAL STRAIN OF CARBON-FILLED COMPOSITE MATERIALS AT HIGH TEMPERATURES. COMMUNICATION 1.

EXPERIMENTAL EQUIPMENT AND INVESTIGATION METHODS

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We describe original techniques and special apparatus for determination of the physicomechanical properties of nonmetallic composite materials in the temperature range 290-3270 K under conditions simulating service conditions: with variation in heating rate, composition, and pressure of the gaseous medium, the nature of the heat supply, etc. We describe a KM-10 apparatus equipped with an original vacuum heating chamber, which we can use for all types of static tests under tension or compression. A specially-developed force gauge mounted in the chamber ensures accurate measurement of the loads acting on the sample over a broad temperature range. We give a description of the DKM-3 dilatometric apparatus, allowing us to determine the thermal strains of samples and structural elements made of composite materials simultaneously with respect to three mutually orthogonal coordinates, along the axis of anisotropy, or at an angle to it. The strain measurements are made using an optoelectronic noncontact system with automatic recording of the readings along three channels and output to a digital printer. The time difference of the readings of $\Delta I$ with respect to the three coordinates is no more than 0.01 sec. In order to compare the results of testing the samples on different apparatus, we chose identical experimental conditions and materials.

In modern technology, many structural elements are subjected to simultaneous action of large heat fluxes and mechanical loads. Composite polymeric and carbonaceous materials have been successfully used for fabrication of thermally stressed structural elements.

In this work, we have investigated the physicomechanical properties of composite materials at high temperatures (up to 3300 K).

Determination of the linear thermal expansion coefficients $\alpha$, the tensile breaking stresses $\sigma_B$, the compressive breaking stresses $\sigma_C$, and other physical parameters for temperatures above 700 K is associated with difficulties due to degradation processes in the polymeric matrices. A rigorous analysis of the phase and structural transformations is also difficult to do, since the charring composites are multicomponent systems in which a number of interconnected processes occur simultaneously. For carbon-filled composite materials, despite the fact that degradation processes within them are completed during the processing stage, upon thermal cycling the physicomechanical properties also may be distinguished by significant instability.

Experimental Equipment. For investigation of the physicomechanical properties of high-temperature composite materials, at the Institute of Problems of Strength, National Academy of Sciences of Ukraine, special techniques have been developed and original apparatus have been designed which allow us to determine the characteristics of materials under conditions simulating service conditions: with variation in the loading rate, the composition and pressure of the gaseous medium, etc., in the temperature interval 300-3300 K.
Mechanical tests were done on a KM-10 high-temperature apparatus (Fig. 1), designed using a standard universal testing machine as a base, additionally fitted with a specially developed universal vacuum heating chamber constructed at the Institute; systems for heating, creating a vacuum and an inert medium; and also a system for registration of the load and the strain.

During the tests, sample 1 is located in chamber 2, clamped on the fixed crosspiece 3 of machine 4. The tests can be carried out in air, under vacuum to 0.13 kPa, or in an inert medium with gauge pressure 0.15 MPa. Gases from the chamber are pumped out with a rotary pump 5 through the valve 6. Atmospheric air is supplied to the pump and to the vacuum chamber through the flow regulator 7. An inert medium is created in the heating zone by admitting argon into chamber 2, fed through the regulator 8 and the valve 9 from the tank 10. The vacuum in the chamber and the gauge pressure of the inert gas was measured by the compound gauge 11 of the OBMV 100-1 to +2.5 type. The samples were heated by radiant heating using the heater 12, connected to the secondary circuit of a single-phase transformer 13 of the OSU-40 type. Heating to the required temperature and maintenance of the temperature at the specified level are accomplished automatically by varying the voltage in the primary circuit of the transformer. Under these conditions, the electrical signal of the feedback thermocouple 14, monitoring the sample temperature, is supplied to the electronic potentiometer 15 of the KSP-4 type. From the potentiometer, the signal (proportional to the sample temperature) is sent to the regulator 16 of the TORT-2 type, where simultaneously a signal is received from the programming device 17 of the RU5-02M type. In proportion to the difference between these signals, the regulator 16 opens or closes the triac 18, thus changing the voltage in the primary and consequently also in the secondary circuit of the transformer. In the apparatus, manual regulation of the temperature is also accommodated, using the regulator 16 or the programming device 17. The thermocouple is chosen according to the medium and the testing temperature. For heating up to 1270 K, we usually use a chromel—alumel thermocouple; up to 2270 K, a tungsten—rhenium thermocouple; for higher temperatures (up to 3300 K), an optical pyrometer.

The load acting on the sample and strain are registered as follows. Electrical signals from the strain-sensitive resistors of the force gauge 19 and the strain gauge are supplied to the strain amplifier 21, then to the XY potentiometer 22, where the stress—strain diagram is recorded. In deciphering the stress—strain diagram, we obtain the values of the quantities $\sigma$, $e$, and $E$.

An advantage of the developed design for the hermetically sealed water-cooled heating chamber includes the possibility (after some minor and uncomplicated operations involving replacing the internal equipment (block, trap, etc.)) of using it for all types of static tests realized by movement of a mobile crosspiece both in the direction of elongation and compression. The gaseous medium for the tests is varied depending on the experimental requirements.

In [12], it is noted that the accuracy of measurements of small stresses is reduced upon heating when using high-temperature chambers in standard loading machines.