Carbonaceous fibrous materials (CFM), which have a broad spectrum of unique physico-chemical properties, have found application in various branches of industry, both directly in the form of fabrics, tapes, and felt, and also in composite materials as a reinforcing filler [1, 2]. However, one of the defects of CFM is their low oxidative resistance at elevated temperatures in such oxygen-containing media as air, water vapor, carbon dioxide, and the like.

It is well known that the thermo-oxidative resistance (TOR) of carbon fibres may be studied by thermogravimetry and derivatography [3]. The reactivity of CFM based on hydrocellulose fibre is reduced with increase in the final heat-treating temperature (HTT), and the temperature range for intense decomposition is shifted into the region of higher temperatures. This method has an important defect: the fibre under study must be ground up to obtain reliable results, which significantly increases the surface of the sample and leads to the appearance of an "end"-burning effect.

In [4], it has been recommended to determine the TOR of a carbon fibre from the time of oxidation to complete loss of fibre strength in air. This method has made it possible to shorten the time for determining the TOR, to eliminate grinding and correspondingly the "end"-burning of the fibre, which distorts the overall picture of burning, and to give more reliable information about the temperature usage range for fibre under the action of mechanical or thermal loads.

The purpose of the studies described in the present article was to determine by the rapid method of [4] the TOR of carbon fibres of the "Ural" type which are prepared from viscose materials and also to find out the temperature ranges of serviceability of these CFM with various final heat-treatment temperatures.

As specimens we chose CFM of fabric structure "Ural-T" (All-Union State Standard (GOST) 28005-88) with various final HTTs: 600, 800, 1000, 1500, 1800, 2200, and 2400°C. Yarns of linear density 85-90 tex were subjected to testing. These were taken from the warp of the fabric.

As is evident from Fig. 1, with increase in the final treatment temperature, the combustion time of the CFM is increased; therefore, it is advisable to carry out testing of these at higher temperatures. With respect to oxidative resistance, the investigated materials may be divided provisionally into three groups: the first with an HTT of 600-1000°C, the second with an HTT of 1500-1800°C, and the third with an HTT of 2200-2400°C. The first group has the minimum TOR. Materials with an HTT of 2200-2400°C display the maximum resistance to oxidation, this being practically identical for one treatment temperature or another. Carbon fibres of the second group occupy an intermediate position.

From Fig. 1, optimum regions of material service with one or another treatment temperature are clearly revealed. For example, fibre with an HTT of 2200-2400°C may be used in air at temperatures not above 450°C, and for short periods at 650°C (~2 h). Fibre with an HTT of 1000°C may be used for an extended period at 200°C, and at 300°C for not more than 2.5 h. The indicated values for service time apply only to carbon fibre of linear density 90 tex and are the minimum values. The reserve in operation, however, of textile articles from such yarns will be higher, since they depend still on the textile form, thickness, weight of material, and other parameters.

From experimental data on combustion time of fibres, we constructed logarithmic dependences for the specific oxidative resistance (W) on the reciprocal of the absolute testing temperature (Fig. 2), where W is the ratio of the combustion time of the fibre to its linear density. All the calculated values of In W for the investigated specimens lie satisfactorily on straight lines.

To determine values of the effective activation energy (E_eff) of the reaction, the experimental data were treated on a computer by the least squares method, taking into account the well-known Arrhenius law. As a function of the final HTT, the calculated values of E_eff so obtained show (Fig. 3) that E_eff increases with increase in the treatment temperature of the material. An increase in E_eff for the oxidation process has also been previously observed [3] in a study of carbon materials with different HTT by the derivatography method.
In connection with the fact that the TOR of carbonaceous materials on the whole is determined by their structural perfection, it was of interest to discover the dependence of its change on change in fibre structure.

The value of \( d_{002} \), which is one of the basic structural characteristics of fibres and which determines the interlayer distance between the basic graphite-like planes, decreases with increase in HTT [1]. This corresponds to the occurrence of a structural ordering process. As is evident from Fig. 3, the overall tendency of change in \( E_{\text{eff}} \) for the oxidation of a carbon fibre as a function of the HTT agrees with the change in its structure during the treatment process. The greatest values of the degree of order and of oxidative resistance in the investigated series of specimens correspond to an HTT of 2200-2400°C.

CONCLUSIONS

− The thermo-oxidative resistance of carbon fibres of the "Ural" type with a final temperature of heat treatment from 600 to 2400°C has been determined in the testing temperature range of 300-900°C in air.

− It has been shown that with increase in the heat-treatment temperature, the oxidative resistance of the material is increased, and the effective activation energy of the oxidation process is raised, which is connected with the structural perfection of the carbon fibre.

− The temperature ranges for use of fibres of the "Ural" grade having various final heat-treatment temperatures have been established.