

GASPHASE IMPREGNATION BY THE PYROCARBON OF POROUS MEDIUMS BY METHODS OF A RADIALLY DRIVEN PYROLYSIS ZONE

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Nowadays it is commonly recognized, that thermogradient gasphase methods are the most perspective for producing high-quality carbon-carbon composites (CCC) [1-3]. These methods were first developed in NSC KIPT and for many years were effectively used to manufacture high-stress compounds of high-temperature nuclear reactor cores and CCC items for rocket engineering [4,5]. For this period a special research-and-production complex of gasphase technologies, which incorporates 12 thermogradient facilities was created. It makes it possible to produce ~40 tons of CCC products per year, including the ones with a diameter up to 2500 mm and a length up to 3000 mm.

The basic scheme of the gasphase installations is represented in Fig.1.

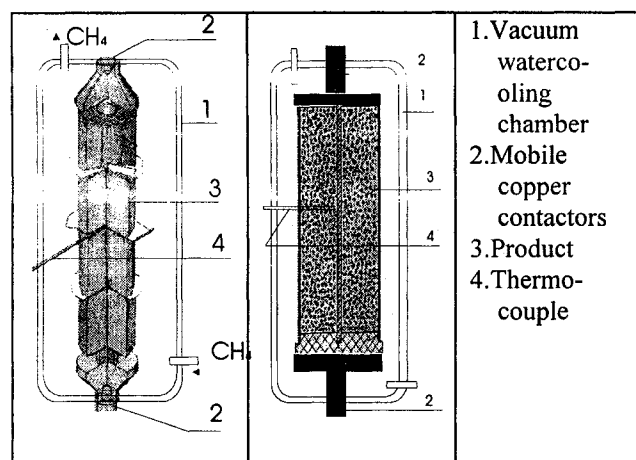


Fig. 1 Basic schematic of the gasphase facilities.

The essence of the methods consists in the fact that porous pre-forms from powders or carbon filaments are resistively heated up in a stream of natural gas (~98 % CH₄). In contrast to thermogradient methods, the process of pyrocarbon deposition takes place in a rather narrow pyrolysis zone. The pyrolysis zone is moved radially at a required velocity from the center to the external surface of pre-form. The outside layer of pre-form is impregnated in the last term, that ensures an effective diffusion of CH₄ into the zone through transport pores. A typical temperature distribution along the radius of pre-form is presented in Fig.2.

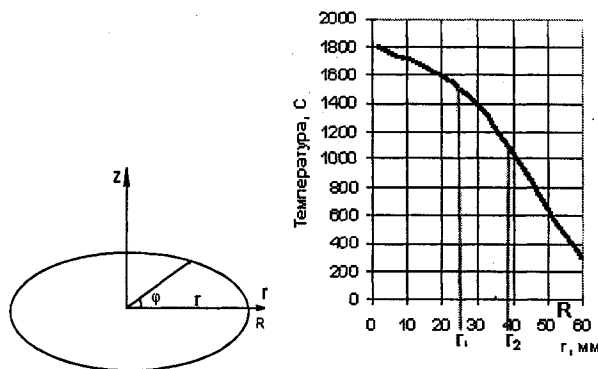


Fig.2 Typical temperature distribution along the radius of a cylindrical porous medium.

We derived the following equation [5] for the velocity of a pyrolysis zone motion:

$$V = \frac{\eta \xi \delta D_0 n_0}{4 \rho T_0} \frac{(T_k + Kn)^2}{r_1 (T_k - KR + Kn) \left(\frac{T_k + Kn}{T_k - KR + Kn} + \ln \frac{R T_k}{(T_k - KR + Kn) r_1} - \frac{T_k + Kn}{T_k} \right)}$$

where, V-velocity of pyrolysis zone motion; η - a portion of carbon in CH₄, 0.75; ξ - factor of transport pore porosity, 0.05-0.1; δ - open porosity; D_0 -factor of mutual CH₄-H₂ diffusion; n_0 - CH₄ density; $7.14 \cdot 10^{-4} \text{ g/cm}^3$; T_k -critical temperature in the pyrolysis zone, 1000-1500°C; r_1 -coordinate of the pyrolysis zone; R- external radius of a pre-form; K-temperature gradient between R and r_1 ; $T_0=273 \text{ K}$.

Figure 3 shows the dependence of V at impregnation of graphite powders in pre-forms 150 mm in diameter up to final densities $\rho_f = 1.4-1.9 \text{ g/cm}^3$ ($\rho_0 = 0.9 \text{ g/cm}^3$, $K=200 \text{ grad/cm}$). The experimentally obtained ρ_f are in a good agreement with the calculated values.

Numerous experiments have demonstrated, that the equation allows us to program well ρ_f at impregnation of various sized pre-forms on the basis of powder and fiber fillers. [4,5]. The proposed theoretical model can also be applied for rapid vapor-phase methods of densification described in the literature[1].

The methods developed are used for manufacturing products from the materials of two main classes: CCC based on carbon filaments and graphites bond by pyrocarbon (GBP). The main properties of these materials are presented in table 1.

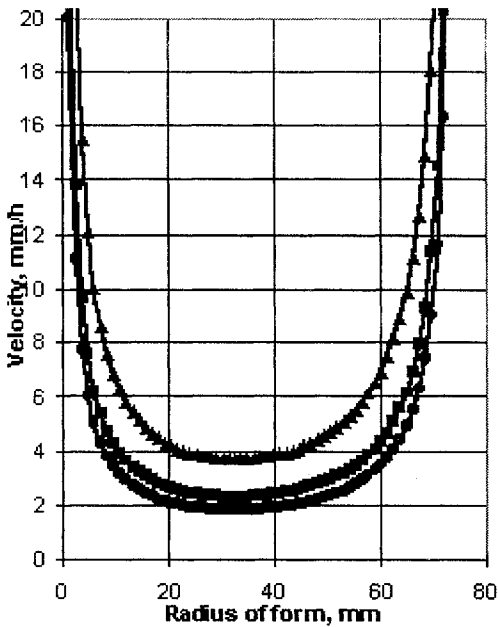


Fig. 3. Calculated velocity of a pyrolysis zone movement for various gradients of temperature.

Table 1.

Some physical and mechanical properties of researched materials.

Characteristics	Materials	
	GBP	CCC*
Density, g/cm ³	1.3-1.9	1.4-1.5
Strength limit at 20°C, Mpa for compression	160-400	150-400
for bend	30-70	100-160
for stretching	25-35	50-120
Electroresistance, 10 ⁻⁶ , Ohm·m at 20 °C	22	40
at 2000 °C	16	18
Heat conductivity, W/m grad for 20°C	10-80	5-7
for 500°C	10-60	7-11
for 1000°C	15-60	10-15
Coefficient of linear thermal expansion $\alpha \cdot 10^{-6}$ grad ⁻¹ for 20-1000°C	4-5	3-4
for 20-1500°C	4.5-5.5	3.5-4.5
Open porosity δ %	6-8	4-7

*THE NOTE: characteristic are taken along the fabric layers.

Figures 3 and 4 show the structure of these materials.

Acknowledgments

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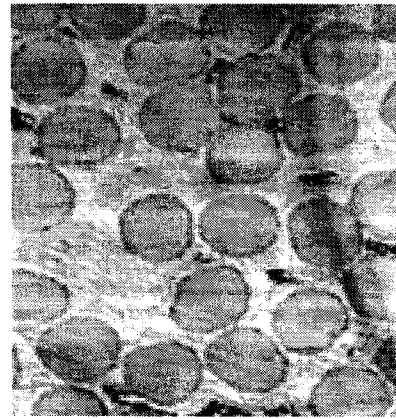


Fig. 4. CCC Structure x1200

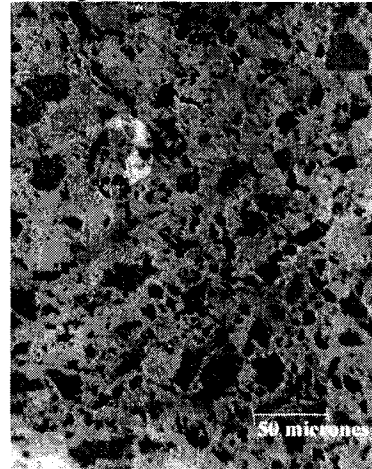


Fig. 3 GBP structure.

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