Investigation of Soot Formation in Diffusive Flames of Acetylene with Propane Additives

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Introduction

Modern conditions of the production of technical carbon (soot) from acetylene by traditional methods for this raw material are attended by the number of peculiarities, which are not widely used. Generally, it is an explosive method of soot obtaining from acetylene; it has a cyclic character. The obtained soot of hard structure and small sp. surface is not widely used.

For perfection of the structure and characteristics of acetylene soot and the method of its obtaining it may be proposed to carry out the process in combustion regime, cutting the soot in this case by NG or propane-butane mixture. Herewith, it is achieved safe regime of acetylene combustion and it is prevented its spontaneous ignition and explosion. Initial researches [1] have shown the perspective of the given direction.

Experimental

There are investigated soot products, obtained in diffusive acetylene-propane flame, at different proportions of two gases.

For research of the process of soot-formation at diffusion combustion of mixtures of acetylene and propane there has been made a laboratory plant. The laboratory plant described in paper [2].

The reactor is represents a tin box, in the cover of which there is a pipe-bend, leading to a bag filter. The size of the reactor is: the length –540mm, the width – 310mm and the height – 340mm. From the one side of the reactor there are two chokes, which regulate air supply. Inside the reactor there are eight jets in two lines. The diameter of jets is 1mm.

The burning of a gas mixture is carried out by a special fuse through an open jet.

Carrying off soot-gas mixture is carried out through a pipe-bend in the cover of the reactor, which is connected one after another with a bag filter and smoke exhauster. The last, in its turn, makes a necessary draught for inflow of the products of combustion reaction. Particulate products (soot) are accumulated on a bag filter and gaseous ones are brought out to the atmosphere.

Rate speed of gases mixture is 2600 cm^3/min, where propane proportion was: 0, 520, 1040, 1560, 2080 cm^3/min.Five soot patterns have been obtained at the following proportions of acetylene and propane in the mixture: 1) 100% - C_2H_2; 2) 80% - C_2H_2; 3) 60% - C_2H_2; 4) 40% - C_2H_2; 5) 20% - C_2H_2, the rest – C_3H_8.

The results and discussing

Soot samples obtained at various proportions of acetylene and propane, were weighed on analytical scales, and soot output has been calculated.

The data of soot output from mixture composition are given in the Table 1.

Table 1.
Dependence of soot output on gas mixture correlation.

Number mixture #	Expense C_2H_2 (cm^3/min)(%)	Expense C_3H_8 (cm^3/min)	Soot exit (p,%)
1	2600(100%)	0(0%)	54%
2	2080(80%)	520(20%)	51%
3	1560(60%)	1040(40%)	44%
4	1040(40%)	1560(60%)	37%
5	520(20%)	2080(80%)	26%

Soot output is decreased with the increasing of propane proportion in the mixture. It is known that alkanes in diffusion flames less disposed to soot generating than alkynes, in this case propane is acting as inhibitor. It is clear from this dependence that acetylene is general source of soot particles nucleus.

It is marked out in the work of Shurupov S.V. [3] that at the pyrolysis of hydrocarbon mixtures, contained acetylene, soot particles nucleus are generated mainly from acetylene, and molecules of other components of the mixture are used for heterogenetic growth of these particles.

Determination of the sizes of crystallites is based on the study of width and form of diffraction maximums and allows to calculate the sizes of particles. The width of diffraction line at a powder rontgenograph is inversely proportional to a linear size of crystallites and by adding some simplifications is showed by the formula:

$$\beta = \lambda A / L\cos\theta$$

where β is the line width at the half of the height of maximum, λ is the length of roentgen radiation, A is a constant, depended on the form of the part, L is an average linear size of crystallites and θ is the angle of diffraction.

In the calculations the value of a constant A, formed the formula, for L_a, calculated at the width of the line /hol/ is A = 0,89.

Therefore, the formulas, determined the size of crystallites of carbon materials in the directions of crystallographic axes **a** and **c**, will look as the following:

$$L_a = 1{,}89\lambda/\beta(hol)\cos\theta(hol)$$
$$L_c = 0{,}89\lambda/\beta(ooI)\cos\theta(ooI)$$

where L_c is an average height of crystallites or laying of graphite layers and L_a is an average diameter of graphite surfaces. Interlaminar interval has been calculated by the equation of Wolf-Bregg:

$$d_{002} = 0{,}0771/\lambda\sin 2\theta_{002}$$

The coefficient of graphitization has been calculated also by the formula:

$$C_r = L_c * 10^{-2}/(d_{002} - 3{,}35)$$

Decomposition of a complex diffraction maximum has been carried out by the method, proposed by Yu.M. Korolev [4].

The structure of obtained soot was determined by roentgen-phase analysis. The data of roentgen-phase analysis are given in the Table 2.

Table 2.
The data of roentgen-phase analysis.

№	Hydrocarbon phase(%)	Graphite phase(%)	For graphite phase				
			d_{002}, A	L_c, A	L_a, A	K_r	ρ_{roen}
1	12	88	3,68	21	65	0,64	2,041
2	10	90	3,69	22	66	0,65	2,035
3	12	88	3,69	21	61	0,62	2,035
4	6	92	3,70	19	63	0,54	2,03
5	10	90	3,70	19	58	0,55	2,03

After desintegration of difractional spectrum there were determined reflexes of the following components: graphite-like phase with d ~ 3,68-3,70. For graphite-like phase the meanings of L_c and L_a, K_r have been calculated too.

As it is shown from the Table 2, the coefficient of graphitization K_r with propane addition is decreasing, while inter-surface distance is increasing. And such parameters as L_c and L_a are little decreasing too. It is evident that propane addition influences on soot structure and makes it less hard.

Specific surface of carbon samples has been determined by the method of heat desorption of argon. This method is based on that by the changing of heat conductivity of gas flow (helium with the addition of argon), passed through the tube with measurable samples, it is determined the quantity of argon, adsorbed by liquid nitrogen and desorpted at the next warming-up of the samples to the room temperature.

Dependence of correlation of gas parts with sp. square (S_{sp}) of the soot obtained is shown on the figure 2.

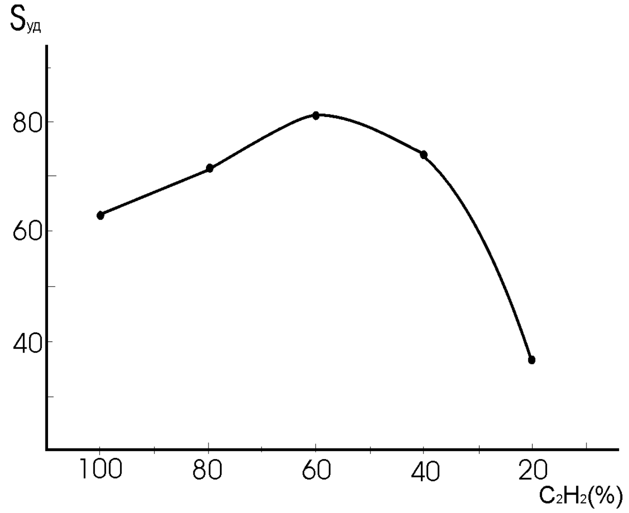
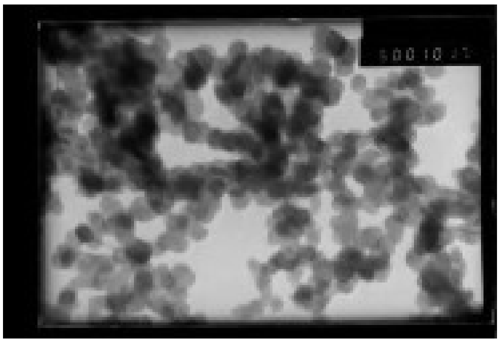
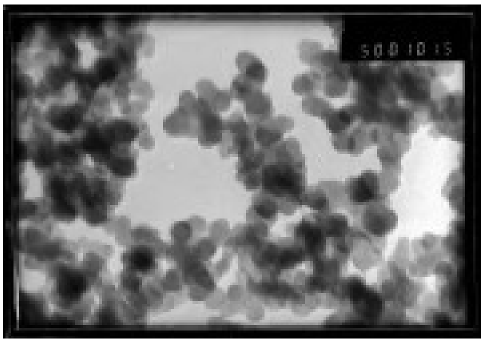


Figure 1. Dependence of sp. square (S_{sp}) m^2/g on correlation of gas mixture (C_2H_2/C_3H_8) %.

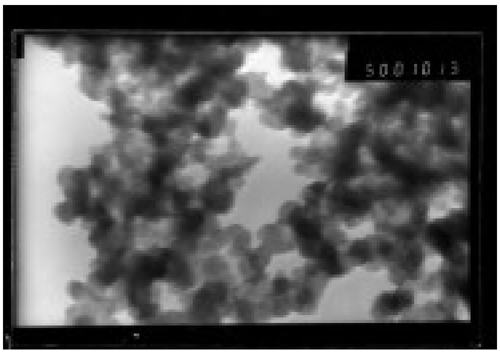
At the figure 3 there are given electronic-microscope pictures of the soot, obtained at combustion a) 100% - C_2H_2; b) 60% - C_2H_2 / 40% - C_3H_8; c) 20% - C_2H_2 / 80%-C_3H_8.



100% C_2H_2
(a)



(60% C_2H_2) / (40% C_3H_8)
(b)



(20% C_2H_2) / (80% C_3H_8)
(c)

Figure 2. Electronic-microscope pictures of the soot.

It is shown from the pictures that with the increasing of propane proportion not only the sizes of the particles are increased (figure 2b) but the degree of their adhesion too (figure 2c). From the results of the research it is appears that pure acetylene soot is less aggregated and it presents itself the particles with the size 600 Å. With the increasing of propane proportion in the mixture there is occurred aggregation of separate soot particles into conglomerates with the size 1200 Å and higher. It is the evidence of that pure acetylene soot has a hard structure and is less aggregated, different particles have spherical form. The data of the pictures and the data of dependencies of soot output on acetylene concentration corroborate that acetylene is a general source of soot particles nucleus.

Conclusion

In the presented paper there is studied the influence of gas correlation in diffusive acetylene-propane flame. From the received data it may be concluded:

Propane at the given regime is acting as the inhibitor. Acetylene is a general source of soot particles nucleus and propane is used for heterogenetic growth of these particles.

Combined consideration of the data of roentgen-graphical investigation and electronic-microscope pictures indicates that mixing of acetylene with propane leads to decreasing of soot output with simultaneous decreasing of graphitization degree. This illustrates the obtaining of technical carbon with less hard structure, which is of particular interest for using as filler in rubber-technical products, etc.

References

[1] Tuleutayev, B.K., Chenchik, D.I., Korolev, Y.M., Mansurov, Z.A. Studying of soot products, obtained in diffusive acetylene-propane flame. The Proceedings of the 3d International Beremzhanov Meeting on Chemistry and Chemical Technology, 2001. PP. 337-338.

[2] Mansurov, Z.A., Tuleutayev, B.K., Chenchik, D.I., Mashan T.T. Proceeding of first international symposium on thermal science and engineering. Beijing, CPR, Soot formation in process diffusive combustion of acetylene with propane additives. 2002. Pp. G-211 – G213.

[3] Tesner, P.A., Shurupov S.V. Soot formation during pyrolysis and combustion, Combustion Science Technology, V. 109, PP. 399-400, 1995.

[4] Korolev, Yu.M. Roentgen-graphical investigations of amorphous carbon systems, Chemistry of Solid Fuel. No. 5, P. 99, 1995.