NATIONAL ACADEMY OF SCIENCES OF BELARUS
A.V. LUIKOV HEAT AND MASS TRANSFER INSTITUTE
BELARUSSIAN SECTION OF THE COMBUSTION INSTITUTE
OPEN JOINT STOCK COMPANY "BELTRANSGAS"
OPEN JOINT STOCK COMPANY "PRIORBANK"

GRANT BRFFR

NONEQUILIBRIUM PROCESSES IN COMBUSTION AND PLASMA BASED TECHNOLOGIES

INTERNATIONAL WORKSHOP

August 26 – 31, 2006
MINSK, BELARUS

CONTRIBUTED PAPERS

Minsk 2006

УДК 533.9+536.46

This book of contributed papers includes the original abstracts of lectures and reports presented at the International Workshop "Nonequilibrium Processes in Combustion and Plasma Based Technologies" (Minsk, August 26 – 31, 2006).

Данный сборник трудов содержит оригинальные тексты лекций и докладов, представленных на международную научную конференцию "Неравновесные процессы в горении и плазменных технологиях" (Минск, 26 – 31 августа 2006 г.).

Редакционная коллегия:

Е.А. Матвейчик, А.Н. Мигун, А.П. Чернухо

Рецензенты:

чл.-корр. НАН Беларуси,
доктор техн. наук, профессор В.Л. Драгун
доктор физ.-мат. наук, профессор Н.А. Фомин

ISBN 985-6456-52-5

© Институт тепло- и массообмена им. А. В. Лыкова НАН Беларуси, 2006

FILTRATION COMBUSTION MODELING OF VISBREAKING OF HIGH-VISCOUS OILS

V.V. KULEBYAKIN, A.V. SUVOROV, E.S. SHMELEV, K.V. DOBREGO

A.V. Luikov Heat and Mass Transfer Institute of NAS of Belarus
15, P. Brovka Str.,220072, Minsk, Belarus

By the present time, the developed geological stock of oils in all world fields achieves the value of the order of 500 milliards tones, among which 300 milliards tones refer to a category of those which are not practically extracted by the modern industry-explored methods of development. At the same time, the oil fraction among all fossils used in the fuel-power engineering and chemical industries of the developed countries is predominant. Of the fundamental problem is the increasing of finite oil transfer of productive beds. The methods of increasing oil transfer of beds are well known [1, 2], but the intensive investigations using the most modern technologies are continuing. It should be also noted that the specific feature of high-viscous oils, whose extraction and transportation are very difficult, is as a rule a high content of paraffins together with a low content of resins, asphaltens and sulphur; which determines their specific value as raw material for the chemical industry. When high-viscous oils are transported by pipelines, the main efforts are directed to improve the rheological properties of oils. To do this, use is made of heating of pipelines, mixing of high-viscous oils with low-viscous ones, simultaneous transportation of water and oil via special pipelines and thermal and vibrational processing of oils, their gas saturation as well as of special additives – depressants. However, the use of these methods is not always advisable. Oils with a large content of paraffins and resin-asphaltens are complex water-oil dispersed systems, in which the evolution process of aggregates, when acted upon by thermal and physical effects, to a considerable extent determines their rheological properties [3]. Therefore, sometimes high-temperature processes are more attractive, among which at present is the process of visbraking that provides a considerable increase in the oil refining efficiency at lower energy expenses.

The main idea of the present study is the use of a filtration combustion wave as a heat source under thermal and physical effects in visbraking devices. As known, the filtration combustion region occupies an essentially small space, as compared to the case of diffusion flame combustion. Combustion occurs very fast, and the concentrations of NOx and CO in its products are by the order of magnitude less than in ordinary flames [4]. The distinctive features of the filtration combustion process thus create unique and qualitatively new possibilities for arranging different regimes of thermal treatment of high-viscous oils to reduce their viscosity.

In future, it is supposed to study these very thermal processes of oil refining, at which high-molecular organic compounds change their chemical composition, decompose and enter into reactions to one another. Apart from obtaining additional amounts of hydrocarbon gases and liquid oil products, these processes enable changing the physical properties of oil, in particular reducing its viscosity, which essentially reduces transportation losses. Reactions of oil hydrocarbons at high temperatures are extremely diverse [5]. In addition to the thermal decay, there occur the reactions of synthesis and partially of isomerization. Some of these reactions are reversible and can proceed in different directions with different rate and different thermodynamic probability. Temperature is the main factor responsible for the above processes. As known, the thermodynamic probability of proceeding the chemical reaction is determined from Gibbs' free energy change. Thermal conversions of oil fractions are a very complex chemical process since an initial product contains a great number of individual components. It is obvious that it is completely impossible to exactly forecast the fate of each of them at high temperatures. In practice, the results on the thermal action are usually judged through the yield of end products and the change in the physical and chemical properties of a mixture. Hydrocarbon start decomposing at 380–400°C. As the temperature is increased, the decay rate grows fast. The residence time in the high-temperature region plays an essential role. Increasing the visbraking temperature and decreasing the residence time in the reaction region, it is possible to obtain the same depth of decomposition of an initial product as at a lower temperature but with a larger duration of the process.

According to the objectives and tasks formulated when stating the problem, the basic scheme of a laboratory setup (see Fig. 1) is designed, with the help of which it is supposed to perform experimental modeling of thermal and chemical processes for different variants of thermal interaction of a filtration combustion wave with oil products. The complexity of this development is that one scheme should realize different regimes of filtration combustion by varying a thermal coupling with the skeleton and the firing regime. As follows from the aforesaid, when oil is subjected to thermal treatment, it is necessary to register temperature values in different zones of the experimental setup, to maintain a controlled supply of oxidant into the filtration combustion region, to provide an assigned flowrate of initial raw – oil, to control and to regulate heat transfer in the zones of heating, reactions and condensation of end products, to provide qualitative and quantitative physicochemical analysis of initial raw and end products. The utilized laboratory setup models tube furnaces for thermal cracking. Heat and reaction zones are located in the upper part of the inner tube (see Fig. 1). It is impossible to exactly establish the boundary between these zones because the raw decomposes simultaneously with its heating. Of principal significance for a temperature regime in these zones is not only the attaining of temperatures, at which there occurs thermal decomposition of oil, but also the prevention of self-ignition (onset of a combustion regime). The preliminary experimental results have shown that optimizing heat transfer conditions only through regulating oil and air flowrates does not create conditions for a stable reaction of thermal decomposition of oil products. So, to do this, different schemes with additional recuperative heat exchangers and heat shields are placed in the zone of filtration combustion. These actions have provided rather stable and controlled heat regimes in the zones of reaction and heating.

More preference has been given to the variant, where temperature is regulated by air supplied to the device for burning waste (after cracking) gases according to the scheme shown in Fig. 1. As the burning of waste gases occurs in dispersed material during filtration combustion, varying the amount of air flowrate essentially does not affect the afterburning quality of waste gases. In addition, the reaction zone has not been thermally insulated, as shown in this figure. Temperature measurements in the zone of preliminary heating of oil and in the reaction zone at different temperatures of the heating jacket of the device (see Fig. 2) have shown that this design allows varying temperature in the cracking zone from 320 to 490 °C with an air flowrate from 1.0 to 0.6 m^3/hr, respectively, which is quite enough to choose optimal conditions for the process to proceed.

The scheme of realization of the visbracking of high-viscous oils is considered when a heat source is represented by a filtration combustion wave. It is shown experimentally that thermal regimes corresponding to the technological peculiarities of the visbraking process can be arranged, including the use of oil thermal decomposition products in the combustion reactions.

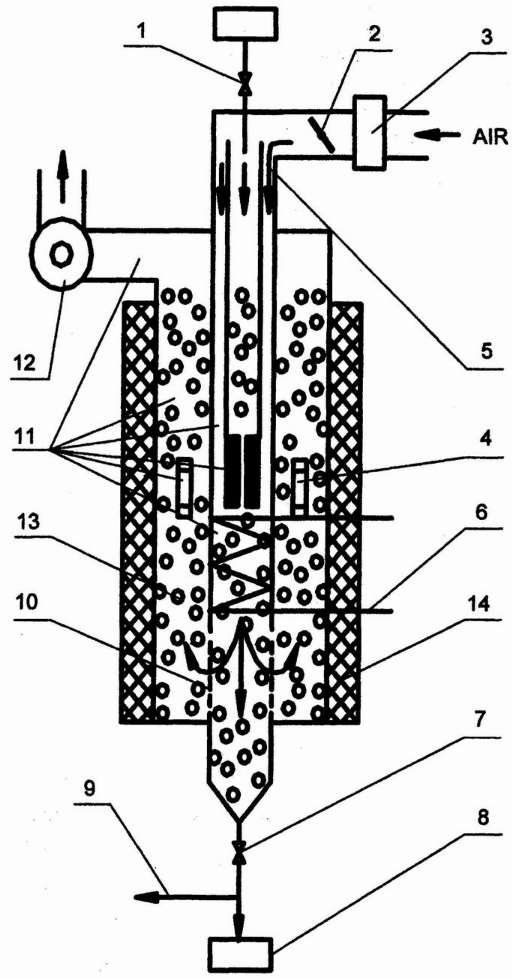

Fig. 1. Scheme of the setup with an air gap in the reaction zone: 1 – batcher of oil mixture, 2 – regulator of air flowrate, 3 – counter of air flowrate, 4 – electric heaters, 5 – air gap, 6 – heat exchanger in the condensation zone, 7, 8 – discharge valve and collector of liquid fractions, 9 – sampling, 10 – gas permeable plates, 11 – thermocouples, 12 – fan, 13 – charging, 14 – thermal insulation

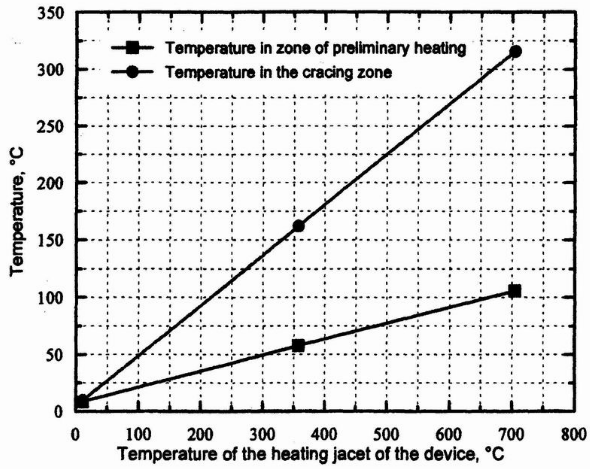

Fig. 2. Thermal regime of the device with temperature air regulation in the reaction zone at an air flowrate of 1 m^3/hr

References

1. Pokonova Yu. Oil and Oil Products: Handbook. St. Petersburg, 2003. 1000 p.
2. Reference book on planning the mining and exploitation of oil fields / Ed. by Sh. K. Gimatudinov. M.: Nedra, 1983.
3. Kulebyakin V.V., Sobolevsky A.S., Kovalevskaya N.D., Yushkina T.V. On the role of the temperature factor in structurizing high-viscous oils // Heat and Mass Transfer –2003. Minsk: HMTI NAS Press, 2003. Pp. 112–116.
4. Dobrego K.V., Zhdanok S.A. Physics of filtration combustion of gases. Minsk: HMTI NAS Press, 2002. 203 p.
5. Kaskova S.I., Dobrego K.V., Kulebyakin V.V. Thermodynamic and kinetic properties of oil basic hydrocarbons and the methods for calculation of their thermal and chemical conversions // Preprint No. 4. HMTI NAS Press, 2004. 39 p.

Научное издание

NONEQUILIBRIUM PROCESSES IN COMBUSTION AND PLASMA BASED TECHNOLOGIES

International workshop
(Minsk, Belarus, 26 – 31 August 2006)

НЕРАВНОВЕСНЫЕ ПРОЦЕССЫ В ГОРЕНИИ И ПЛАЗМЕННЫХ ТЕХНОЛОГИЯХ

Международная конференция
(Минск, Беларусь, 26 – 31 августа 2006 г.)

Ответственный за выпуск А.Н. Мигун

Подписано в печать 16.08.2006.
Формат 60x84 1/16. Бумага офисная.
Усл. печ. л. 12,2. Уч.-изд. л. 21,9.
Тираж 85 экз. Заказ 78.

Институт тепло- и массообмена им. А.В. Лыкова НАНБ.
220072, Минск, П. Бровки, 15.
ЛИ № 02330/0133066 от 30.04.2004.

Отпечатано на ризографе Института тепло- и массообмена им. А.В. Лыкова НАНБ. 220072, Минск, П. Бровки, 15.

ISBN 985-6456-52-5
9 789856 456520