DEVELOPMENT OF GASOLINE BLENDING RECIPES TAKING INTO ACCOUNT VOLUME AND COMPOSITION OF THE INVOLVED FEEDSTOCK

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Gasoline and diesel fuel are the most significant and important part of petroleum products which play crucial role in economics of Russian Federation. On a modern refinery, the most part of crude oil is being refined into motor fuels, primarily in gasoline. From year to year the total production volume of oil-products increases, along with the increase of oil conversion ratio; however, ecological and operational qualities of automobile gasoline have been tightened. This makes gasoline blending an important process for petroleum industry with the main goal to mix products of refinery processes in specific proportions and obtain a final blend that complies all quality requirements [1].

This multi-staged process is one of the most sophisticated technologies from the standpoint of economic efficiency. First of all, detonation resistance does not follow the law of additivity (octane number is a non-linear characteristic), it leads to more difficult optimization the process. In addition, equally important point lies in complexity of feedstock mixtures which consist of large quantities of individual hydrocarbons, in conditions of ever-changing feedstock composition. Considering all above mentioned factors, it appears to be impossible to formulate a universal blending recipe; existent recipes need to be revised in real time to correspond the changing conditions of blending.

Thus, optimization of trade gasoline blending process is an urgent industrial-oriented research direction in terms of the modern trends of annual increase in demand of high-octane gasoline. There is a large number of research works of domestic and foreign scientists dedicated to the study of aspects of this problem [2].

However, the most efficient way of optimization and of gasoline blending process and prediction of operational properties of blended gasoline is to apply modeling systems which use physic-chemical properties of hydrocarbons as a basis for calculations. The main role of such systems is to formulate economically feasible recipes of gasoline blending considering the composition of the involved feedstock.

During the research, complex system for optimization of gasoline production was developed (Figure 1). The following interconnected modules are presented in the system:

- Module of chromatographic data systematization;

- Module of detonation and physic-chemical characteristics calculation;

Fig. 1. The structure of complex modeling system for optimization of gasoline blending

The developed modeling system provides user with calculations of detonation properties and wide range of physical and chemical characteristics of gasoline and gasoline components including octane number, vapor pressure, density and viscosity of mixtures and precise hydrocarbon composition of each streams based on chromatographic analysis data. On the basis of this data, the system calculates an economically optimal gasoline recipe for different brands of gasoline.

Module of chromatographic data systematization: in this modeling system, chromatography data of feedstock streams serve as an input data for calculations of detonation characteristics. In view of the fact that hydrocarbon composition gasoline component streams varies significantly in set and number of hydrocarbons, the module of chromatographic data systematization “UniChrom” has been introduced into the system for unification and standardization of experimental chromatography data.

Systematization of the chromatography is an automatic process constituting the reclassification of hydrocarbons in the initial mixture to the set of 110 key components. This set serves as a baseline for high accuracy calculations of octane numbers of blending gasoline. This set includes both individual hydrocarbons and pseudo-components.

Module of detonation and physic-chemical characteristics calculation provides calculations for the following detonation characteristics of gasoline:

1. Octane numbers (RON, MON) of hydrocarbon stream involved into the blending process taking into account their non-additivity;
2. Mixture density, by the Mendeleev formula;
3. Mixture viscosity, by the Orrick and Erbar formula;
4. Saturated vapor pressure (SVP) by the Antuan equation;
5. Aromatics, olefins hydrocarbons and benzene percentage.

The main module is developed in Borland “Delphi 7” workspace combining a user-friendly interface, coordination, integrity of sub-components and stable functioning of system in general. It is possible to manually change flow rates of input streams [3].

Module of optimal gasoline blends: from the standpoint of economical profitability of the refinery, optimal blend of gasoline must ensure the biggest economic effect: Refinery has to use the cheapest raw materials for blending of gasoline with low market value (low-octane brands) and the cheapest raw streams, and high-octane raw streams for the most commercially demanded brands, respectively. Refinery tends to produce the maximum possible volume of gasoline, using available stocks of raw stream; the product must comply with the demands of the Russian Technical Regulations and State Standard R 51866-2002.

In the research, a logical algorithm was compiled on purpose to formulate optimal blending recipes. In this algorithm, 12 typical hydrocarbon streams are involved into the blending process. Limiting conditions in recipes formulation are strictly regulated characteristics as RON, MON, SVP and content of benzene, aromatic and olefin hydrocarbons, sulphur and MTBE in trade gasoline of a specific brand.

The module of optimal gasoline blends formulation was developed in the workspace Borland "Delphi 7" on the basis of the algorithm flowchart of the logical algorithm is presented in Figure 2.

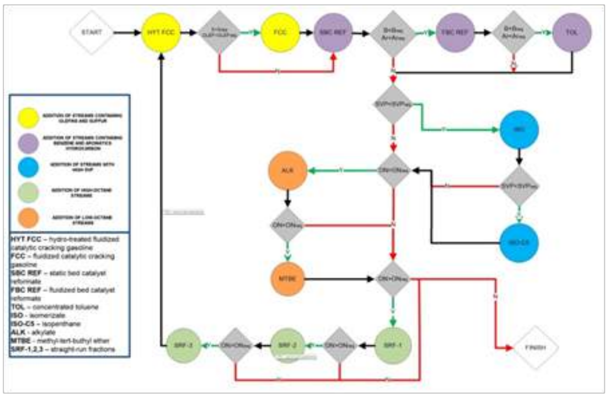

Fig. 2. Flowchart of the logical algorithm for optimal gasoline blends formulation

The developed algorithm automatically optimal gasoline blends on the basis of a formalized hydrocarbon composition of involved streams and predicts all detonation characteristics of blended gasoline. Gasoline blending is carried out step-by-step as well as recalculation of required quality characteristics.

Priority of using streams is chosen to way of the biggest resource saving production. So first use the lowest-quality (and therefore least expensive) components, and then, when that streams are consumed, or used as much as possible, involve more expensive components.

The proposed approach has several advantages: first of all, it becomes possible to respond to changes in composition of raw materials, develop "flexible" blending recipes and formulate recommendations for the involvement of streams with different composition when the blended to different gasoline brands.

Secondly, the algorithm is aimed to the efficient solution of several technological situations: production of the certain volume of gasoline, maximization of the particular brand yield, and combination of several gasoline brands with an ability to set "the priorities of sequence".

Thirdly, the algorithm reflects the concept of resource-saving blending, which allows to saving the most expensive components, involving unspent reserves only into the production of high quality fuels and reducing of unwanted quality giveaways and production of off-grade gasoline. These measures are able to increase the economic efficiency of blending, using only internal resources of the refinery without additional investments.

During the work, optimal blending recipes for Premium-95 gasoline brand (Euro-5 quality) were formulated using the developed complex modeling system. Joint and separate production regimes are simulated. Also influence of changes in hydrocarbon composition of feedstock on detonation characteristics of gasoline is shown. In case of change to the worst-quality feedstock, correction of recipes allows avoiding production of off-grade gasoline; it is also possible to save high-quality components in case of change to the best-quality feedstock.

It was established that for resource-efficient maintenance of gasoline blending process it is necessary to correct blending recipes considering the hydrocarbon composition of involved feedstock and non-linear nature octane numbers throughout blending operations.

The developed modeling system allows increasing the efficiency of the gasoline production using only internal resources of the refinery with no additional investments and expenses. Corrections of gasoline blending recipes considering changes in composition of the involved feedstock allow avoiding undesirable quality giveaways trade gasoline and overruns of expensive components. The results show the concept of the resource-efficient gasoline production which makes large economical effect for the refinery.

References

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