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Energy and exergy analysis of an aromatics plant

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ABSTRACT

Energy and exergy balances were evaluated for the units that constitute the Aromatics plant of a refinery in Portugal (FAR): pre-distillation (Un-0100), Arosolvan (Un-0200), Parex (Un-0300), Isomar (Un-0400) and production of solvents (Un-0500).

The FAR had an overall energy yield of 0.81% and an exergetic efficiency of 65.9%. The equipment with higher energy losses, were the condensers, representing 25.9% of the energy losses, followed by air coolers, with 15.4% of the energy losses. The furnaces were in third place with 14.7% of the energy losses. Most of the energy lost in FAR was due to the cooling process. The irreversibilities observed in the condensers and air coolers were equivalent to 1.61% and 0.86% of the total plant irreversibility. Furnaces represent 14.7% of energy losses, but stand out above the irreversibilities analysis with 14.5% of the total. This equipment presents a high potential of energetic and exergetic performance improving, with natural positive impact on energetic and exergetic performance in the FAR.

The unaccounted thermal losses represented 32.9% which is mainly justified by the unknown mass flow rate of the gaseous effluent burned in the flare.

1. Introduction – the energy in the petrochemical industry

One of the biggest challenges for mankind in the 21st century is to find out new ways to increase the availability of high exergy energy and, at the same time, to minimize climate impacts. For oil refineries, this challenge is even more important, because it is also necessary to enhance the quality and the profitability of their products. Most of the times, the obligatory investments aim to a decrease of the emission of greenhouse gases, but, frequently, such is not accompanied by a production increase. One way to minimize the undesirable gaseous emissions and to increase the production is the process optimization, leading to a better energy efficiency of the involved technological processes [1].

According to the thermodynamic laws, the energy analysis of technological systems can be carried out through two distinct ways. The analysis through the first law of thermodynamics is an analysis based on energy conservation principles and is supported by the concept that energy can be only transformed but never created or destroyed [2]. However, in any energy process, there is always a certain amount of high quality energy that is converted into lower quality energy [3]. In spite of this, the energy balances always place the different energy forms at the same level and give no information as far as internal losses are concerned. The other kind of energy analysis is based upon a combination of the first and second law of thermodynamic, the exergy analysis. The exergy balances are similar to the energy ones, nevertheless they consider, not only the amounts of energy being processed, but also their qualities. Since the quality of the energy can be destroyed, this means that the balances under analysis have to take into account the degradation of the quality of energy that flows through

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the boundaries of the control volumes. This destruction of the quality of the energy is tied to the energy that is being wasted, or inadequately used because of the fact that all real processes are irreversible [4].

An exergy balance of any equipment or process can say quite a lot about its potential in terms of the useful work that is being processed, while the exergy destruction, or losses, is a quantitative measure of the process inefficiencies [4]. The exergy analysis has been lately considered a key tool for the definition of a more sustainable society. In fact, the exergy analysis has been used in the design and simulation of thermal, electrical and chemical systems. The obtained data can be used for the development of programs suitable for the definition of national energy policies [5].

Costa et al. [6] developed a program to calculate the exergy efficiency of distillation columns and found that exergy analysis was vital to find out energy deficiencies in the industrial processes and as such this technique should be used in process design and optimization. Fábrega et al. [7] through the exergy analysis of the refrigeration cycles in the production of ethylene and propylene reached the same conclusion, stressing that this technique is a useful guiding tool for the rational use of energy. Khoa et al. [8] proposed new exergetic methodologies for the optimal design of distillation columns, while Benali et al. [9] described a specific application of energy consumption improvement, through changes in the process flow of atmospheric distillation of petroleum and quantified the energy degradations in the distillation columns. More recently [10] different methods for thermal energy integration in a distillation column for the separation of benzene, toluene, xylenes and C9 isomers were carried out. The thermal energy integration path was also studied in [11] whereas the concern on the definition of energy efficiencies for the oil and gas industry was discussed by Nguyen et al. [12].

But there are not many studies on the plants as a whole and the present work concerns the aromatics plant from this refinery (FAR) which can handle 850,000 t/year of reformate that is supplied by the fuel plant of the same refinery or from other sources. The following scheme explains in a simplified way the operation of the aromatics plant as well as the interconnections among its subunits (Fig. 1).

2. Methodology of the analysis

The first step of the study was to perform an overall energy balance of the plant. A global energy efficiency of the plant was determined, corresponding to the ratio between the useful output energy in the process flow currents and the consumed energy. In the second step, the energy analysis was complemented by an exergy analysis, looking at the qualities of the several energy forms that were handled in the process. The main objective was not to question the technological process being followed in the FAR, but to find out situations where the exploitation of energy wastes and losses could improve the energetic performance of the plant in its present operating layout.

In order to perform such energy assessment, a scrutiny of the different energy quantities involved in the subunits of the plant was carried out according to the energy balance sheets of the company from January to July 2011. Based on the daily energy consumption, processing currents mass flow rates, as well as temperature and pressure readings, monthly and annual average values were determined. This corresponded to a total of 156,000 data values. Whenever necessary, mass and energy balances of the equipment were executed in order to complement missing values from the plant data sheets.

The energies supplied to this plant were electrical, chemical and thermal. The electricity was consumed by pumps, fans and lighting. The chemical energy was supplied as fuel oil and fuel gas from the refinery. The thermal energy was composed

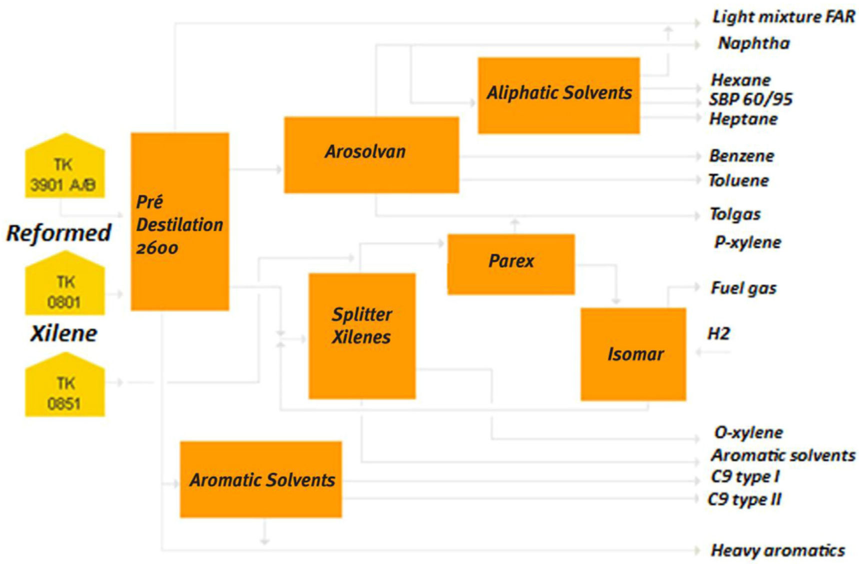

Fig. 1. The subunits that compose the aromatics plant from the refinery.