Fuel Processing Technology 119 (2014) 204–210

Contents lists available at ScienceDirect

Fuel Processing Technology

journal homepage: www.elsevier.com/locate/fuproc

Separation of solvent and deasphalted oil for solvent deasphalting process

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ARTICLE INFO

Article history:
Received 2 April 2013
Received in revised form 2 November 2013
Accepted 21 November 2013
Available online 6 December 2013

Keywords:
Solvent deasphalting
Deasphalted oil
Hexane
Pentane
Separation

ABSTRACT

Due to the depletion of conventional oil resources and increasing prices, various technologies for utilizing unconventional oil and low-value crude residues, which have not been fully exploited, are currently being explored. The exploitation of unconventional oil and low-value crude residues requires upgrading processes such as carbon rejection and hydrogen addition. Among many existing upgrading processes, solvent deasphalting (SDA), a technology for removing asphaltene-rich pitch and producing higher-value deasphalted oil (DAO) by using paraffinic solvents, is promising because it offers the advantages of low installation cost and flexibility in terms of the control of the quality of pitch and DAO. The SDA process requires a considerable amount of expensive solvent. Thus, solvent recovery, an energy-intensive process, is required for improved efficiency. In this paper, DAO/solvent separation experiments were carried out using two solvents, pentane and hexane, to investigate the effect of operating conditions such as temperature, pressure, and DAO/solvent ratio on the process. The DAO/pentane separation was superior to the DAO/hexane separation under similar conditions. Regardless of the solvent type, solvent recovery was increased as the DAO/solvent ratio in the feed was decreased. Solvent recovery was strongly influenced by variations in temperature but was relatively insensitive to changes in pressure.

1. Introduction

High-value petroleum products such as gasoline, naphtha, jet fuel, kerosene, and diesel are usually produced by distillation. Distillation of crude oil at or near atmospheric pressure produces gas oil (9–14 wt.%) and distilled oil (25–35 wt.%) from the top and atmospheric residue (35–65 wt.%) from the bottom, the composition of which depends on the properties of the crude oil. Further distillation of the residue from the atmospheric distillation under reduced pressure generates vacuum gas oil, distilled oil (25–40 wt.% of crude oil), and vacuum residue (10–25 wt.% of crude oil). Since the vacuum residue contains asphaltene compounds that include a large amount of heavy metal, sulfur, and nitrogen, and since it is highly viscous, it does not readily lend itself to use as transportation fuel; however, the heavy hydrocarbon oil content of 50–80 wt.% makes it amenable to produce high-value petroleum products after separation [1–4]. Consequently, several techniques for separating the high-value oil fraction from the vacuum residue have been developed and commercialized, including extraction, pyrolysis, catalytic decomposition, catalytic hydroconversion, and gasification. In general, these processes are performed under high temperature conditions, and they require a considerable amount of fuel, steam, and cooling water for operation, thereby increasing the cost of vacuum residue upgrading and limiting the utilization of vacuum residue [5].

Solvent deasphalting (SDA) is considered to be a viable solution to the energy overconsumption problem. Operation costs may be reduced in the SDA extraction technique by using relatively low-temperature and -pressure conditions. A high yield of deasphalted oil (DAO) can be achieved in the SDA process by removing asphaltenes based on conglomeration and sedimentation. Moreover, the design of the SDA process is relatively simple, and scale-up can be carried out easily. Fig. 1 shows the scheme for the SDA process. The instrumentation includes a solvent extractor, DAO/solvent separator, and pitch stripper. Compounds are dissolved within the solvent extractor, except for asphaltene, and a mixture of DAO and solvent is obtained upstream, whereas asphaltene-rich pitch containing a small amount of solvent is drawn downstream. The mixture of DAO and solvent is separated in the DAO/solvent separator to produce DAO, and the recovered solvent is recycled to the extractor. In the pitch stripper, a small amount of residual solvent is separated for recycling, and concentrated asphaltene

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http://dx.doi.org/10.1016/j.fuproc.2013.11.014

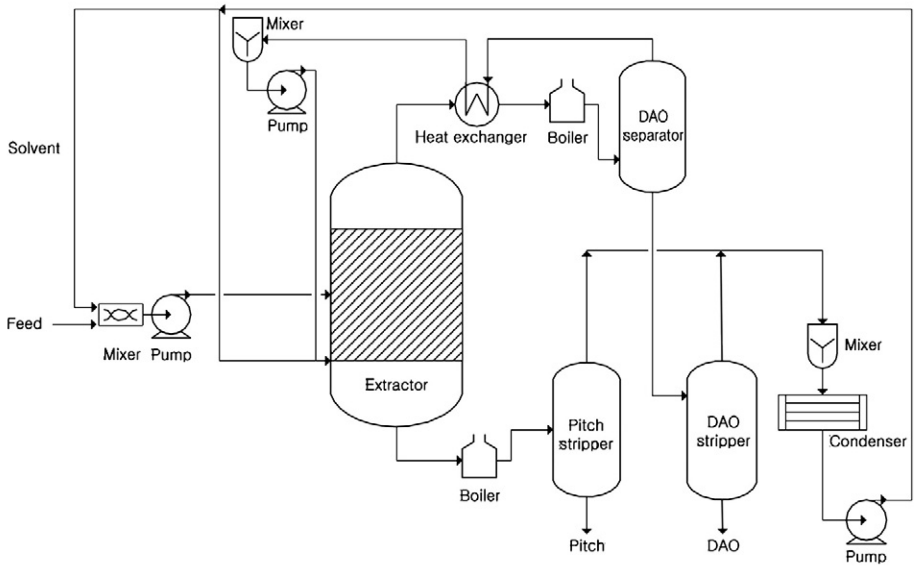

Fig. 1. Schematic diagram of solvent deasphalting process.

(pitch) is produced. The DAO produced from the SDA process is generally used for lube base oil and may be further converted into transportation fuel and chemical raw materials through additional refinement. The asphaltene (asphalt binder) is used as a road-packing material or low-grade fuel, and can be utilized to produce heat and hydrogen by gasification [6–10].

C3–C6 solvents are generally employed in the SDA process. Increasing carbon number of the solvent reduces the quality of DAO but enhances the yield of DAO produced, due to the increased average molecular weight of hydrocarbons that are soluble in the solvent [9]. Propane and butane have been widely utilized in the SDA process to generate high-quality DAO. The recent increase in the demand for light oil has increased the need for effective heavy oil upgrading for high-yield production. Accordingly, high-carbon-number solvents, such as pentane and hexane, have been explored as solvents for SDA processes [11–13].

Previous studies on SDA have focused on extracting DAO under various conditions, targeting maximum utilization of the vacuum residue. Baek et al. [14] investigated the effects of temperature and pressure on the oil-extraction yield in the respective temperature and pressure ranges of 210–250 °C and 42–122 bar, using *n*-pentane as a solvent for extraction. The oil-extraction yield was found to increase with increasing pressure and at the temperature approaching a critical point. Cao et al. [15] evaluated the effects of solvent composition, temperature, and solvent-vacuum residue ratio on the oil-extraction yield

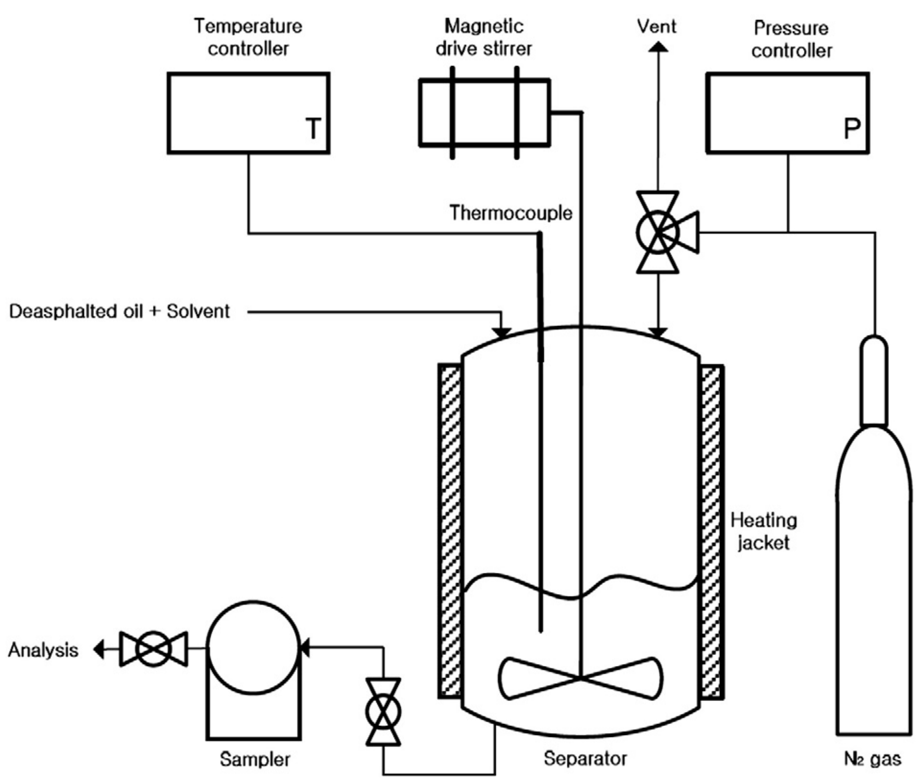

Fig. 2. Schematic diagram of experimental apparatus for DAO/solvent separation.