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Research article

Dependence of visbroken residue viscosity and vacuum residue conversion in a commercial visbreaker unit on feedstock quality

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Nine vacuum residual oils were characterized and eight blends of them were processed in the LUKOIL Neftohim Burgas commercial visbreaker unit. It was found that at constant content of about 8 vol.% of the fraction boiling up to 360 °C (diesel cut) in the visbroken residue the visbroken residue viscosity correlated with the vacuum residual oil visbreaker feed viscosity with a squared correlation coefficient $R^2 > 0.98$. By application of correlation analysis and intercriteria analysis the vacuum residual oil feedstock parameters which have statistically meaningful impact on conversion to product boiling below 360 °C were found to be vacuum residual oil sulfur and hydrogen content, and solubility power of maltenes. The results obtained in this work are consistent with those obtained from other groups, even for other types of vacuum residue processing like ebullated bed hydrocracking. The vacuum residual oils which contained more resinous-asphaltenic materials formed more asphaltenes in the process of thermal conversion. The vacuum residual oil viscosity increment with increasing of asphaltene content for the straight run vacuum residual oils can be described by a second order polynomial. The secondary vacuum residual oils — the visbroken vacuum residual oils exhibited a lower than straight run residual oil dependence of the residue viscosity increment on increasing of the asphaltene content.

1. Introduction

Diversifying crude slate creates opportunity to improve profitability of oil refining [1]. Refinery LP models are typically used to evaluate which crude could be beneficial for processing in a refinery. The best way for selection of a crude after evaluating the risk of processing of high corrosion and fouling propensity feedstock, which can cause unplanned shut-down and reduced safety of operation, is to have rigorous models of the refinery units that will create yields and properties of oil products which are to be inputted for the LP model. However, this is rarely the case and then only refinery LP model is used to evaluate the profitability of processing of certain crude. The factors that have the biggest impact on refinery profitability are conversion level, yield structure and product properties of conversion units like FCC and residue thermal cracking (visbreaking). Among them visbroken residue viscosity turns out to have a significant effect on refinery margin. Then the question about the value of viscosity of the unconverted visbroken residue obtained from different feedstocks deserves a special attention. An earlier study has shown that visbroken residue viscosity can fluctuate even during processing of the same feed (vacuum residue) which illustrates the complexity of this subject [2]. Brauch et al. investigating correlations between some characteristics (density, viscosity, asphaltene and sulfur contents, stability) of the vacuum residues and products of their visbreaking have shown a relatively high dispersion of the data resulting in low correlation coefficients of the developed correlations [3]. In order to further illustrate the complication of this matter data of viscosity of the unconverted residue obtained in the LNB VBU during processing of the crudes REBCO, and blends of REBCO with Basrah (Iraq crude), Kirkuk (Iraq crude), HICO, Varandey (Russian crude), Tomsk atmospheric residue (Russian AR), and RAYG atmospheric residue (Russian AR) are presented in Fig. 1. It should be noted here that except REBCO no other crude has been processed at 100% in LNB refinery. The typical blend of REBCO plus other crude from which the vacuum

Abbreviations: AR, atmospheric residue; DAO, deaspalted oil; HCO, heavy cycle oil; HICO, heavy Iranian crude oil; FCC, fluid catalytic cracking; LNB, LUKOIL Neftohim Burgas; LP, linear programming; LHSV, liquid hourly space velocity; RPMS, refining and petrochemical modeling system; REBCO, Russian export blend crude oil; SARA, saturates, aromatics, resins and asphaltenes; VIS, viscosity; VGO, vacuum gas oil; VRO, vacuum residual oil; VBR, visbroken residue; VBVRO, visbroken vacuum residual oil (>540 °C); VB, visbreaker; VBU, visbreaker unit.

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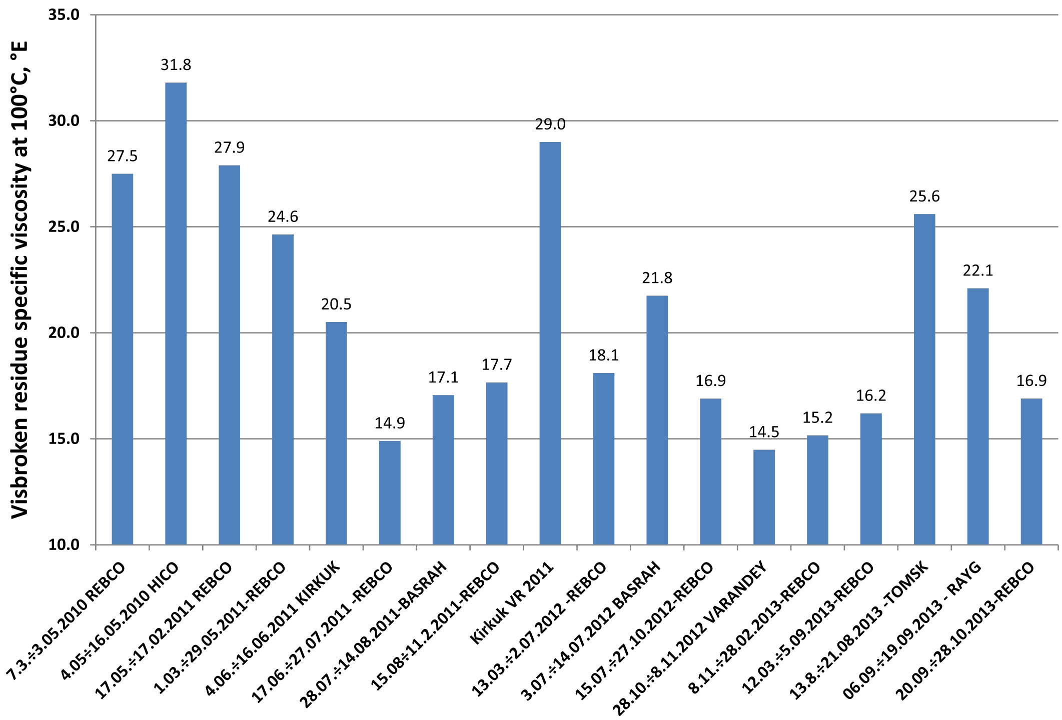

Fig. 1. Variation of visbroken residue viscosity during processing different crudes in the LNB VBU.

residue feeding the LNB VBU was formed consisted of about 75% REBCO and about 25% other crudes. It can be seen from the data in Fig. 1 that viscosity of the visbroken residue, obtained from 100% REBCO vacuum residue has varied between 14.9 and 27.9 °E (specific viscosity in degrees Engler measured at 100 °C). The aim of this work is to evaluate the effect of processing of different feeds (blends of REBCO and other crudes) on conversion level and on the value of the unconverted residue viscosity in the commercial LNB VBU.

2. Experimental

Nine vacuum residual oils were used in this study. They were obtained by atmospheric and vacuum distillation of the crude oils REBCO, Basrah, Kirkuk, Varandey, El Bouri (Libian crude), Kazakh (Kazakhstan crude), and RasGharib (Egypt crude) and vacuum distillation of the imported atmospheric residual oils Tomsk and RAYG. The atmospheric distillation was performed in TBP Euro Dist System from ROFA Deutschland GmbH, designed to perform according to ASTM D2892 requirements. Its fractionation column is equipped inside with packing, equivalent to 15 theoretical plates and the condenser provides the standard's mandatory reflux ratio of 5:1. The vacuum distillation of the atmospheric residual oils was carried out in Potstill Euro Dist System according to ASTM D5236 requirements. Density, characteristic factor Kw and distillation characteristics of the vacuum residual oils and atmospheric residual oils are presented in Table 1. The vacuum residual oil distillation characteristics were obtained by extrapolation of the distillation data of the atmospheric residual oils employing Riazi's boiling point distribution model [4]. Table 1 presents data of Riazi's boiling point distribution model parameters A_T, B_T, and also data of squared correlation coefficient R^2 (higher than 0.99 for all atmospheric residual oils)

Table 1
Distillation characteristics and characteristic Kw-factor of the residual oils under study.

AR	REBCO	Basrah	Kirkuk	Tomsk	RAYG	Varandey	El Bouri	Kazakh	RasGharib	VBR REBCO	VBR 35% RasGharib/10% Kirkuk/10% Kazakh/45% REBCO
d_4^{20}	0.9425	0.9794	0.9854	0.9758	0.955	0.9225	0.9645	0.9128	1.0063	1.0109	1.0242
T_{50}	523	537	535	557	519	488	517	532	577	572	640
Kw	11.96	11.58	11.50	11.72	11.79	12.04	11.66	12.40	11.45	11.38	11.52
Riazi boiling point distribution model parameters											
IBP, °C											
A_T	0.316	0.293	0.268	1.589	0.429	0.216	0.326	0.384	0.427	6.054	2.596
B_T	1.163	1.328	1.439	2.665	1.704	1.147	0.940	1.066	1.222	3.575	2.215
R^2	0.9998	0.999	0.997	0.998	0.999	0.999	0.9993	0.9996	0.9997	0.991	0.998
VR distillation characteristics											
IBP, °C	540	540	541	538	541	540	542	542	540	539	539
10%	553	558	558	561	557	552	562	567	567	566	577
30%	578	599	576	603	595	585	616	621	628	616	652
50%	605	645	637	650	641	628	689	690	706	664	733
70%	657	716	702	703	704	692	798	803	814	719	832
90%	751	855	812	811	826	798	1016	1001	1020	815	991
95%	781	961	900	847	888	876	1184	1148	1128	861	1066
FBP	1150	1037	963	916	946	952	1240	1203	1383	940	1229
Kw	11.64	11.39	11.28	11.13	11.55	12.01	11.60	11.97	11.40	11.40	11.50

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