ISSN 1068-364X, Coke and Chemistry, 2020, Vol. 63, No. 5, pp. 253–256. © Allerton Press, Inc., 2020.
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CHEMISTRY

Refining of Coal Tar by Hydrogenation in the Presence of Nanoheterogeneous Nickel Sulfide Catalyst

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Received February 12, 2020; revised February 12, 2020; accepted April 20, 2020

Abstract—The refining of coal tar by hydrogenation is considered. In this process, nanoheterogeneous Ni-based catalysts may expediently be produced in situ from precursors in the reaction medium. The yield of needle coke in complete coal processing with recirculation of the residue at the coking stage is found to be 50–55%. That is 1.5 times the industrial yield in the coking of pitch.

Keywords: coal tar, hydrogenation, refining, nanoheterogeneous nickel sulfide catalysts, needle coke

DOI: 10.3103/S1068364X20050038

Coal tar, a coking byproduct formed in the pyrolysis of coal at 800–900°C, contains numerous reactive compounds, which undergo condensation after distillation at 350–380°C, with the formation of pitch fractions that do not boil below 380°C.

The pitch fractions of tar that boil above 350–380°C are used directly as binder in electrode production or are first oxidized to increase their softening temperature and the yield of pitch coke. The coke obtained from high-temperature pitch is predominantly of isotropic structure and may be used to produce anodes and artificial graphite for the construction industry. However, they are unsuitable for the production of graphitized electrodes and cathode modules in aluminum electrolysis tanks. Those components are produced from anisotropic needle coke [1].

Coal pitch may be divided into four main fractions, in terms of solubility

1. The γ fraction, which is soluble in isooctane, determines the liquidity of the whole system, as well as the viscosity and wettability of pitch.

2. The β fraction, which is insoluble in isooctane but soluble in benzene and toluene, determines the binding and sintering properties of the pitch.

3. The α_2 fraction, which is insoluble in toluene but soluble in quinoline, determines the sintering and coking conditions of the pitch, as well as its susceptibility to graphitization.

4. The α_1 fraction, which is insoluble in quinoline and unreactive, may be a gas or a liquid. In either case, it prevents the formation of block structures in graphitization, thereby constraining the formation of anisotropic needle coke in pitch coking.

To obtain anisotropic (needle) coke, the coking batch must have a minimal content (no more than 1.0%) of the α_1 fraction. Its content in pitch depends on the method of batch preparation [2].

By varying the content of the quinoline-insoluble fraction in the pitch, the properties of pitch coke may be adjusted over a wide range. Likewise, the microstructure of the coke may be regulated. That is accomplished at Japanese plants, which supply not only isotropic coke for the production of high-strength construction-industry graphite but also needle coke for graphitized electrodes, as well as anodic coke of intermediate quality, with structural components that differ greatly in size. Note that the specifics of the production of needle coke from purified coal tar are the commercial property of the manufacturers; practically no information is available in the literature.

The reactive compounds in tar may be stabilized before its preparation (heating for distillation, pitch coking, etc.) by hydrogenation in the presence of finely crystalline nanocompounds of metals such as Mo, Ni, Fe, and W, comparable in size with the tar molecules [3, 4]. In terms of effective dispersion, nanoheterogeneous catalysts produced in situ from precursors in the reaction medium are most promising [5].

The precursors employed may be water-soluble [3, 6] and oil-soluble [7] transition-metal compounds.