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Hydropyrolysis of a Turkish lignite (Tunçbilek) and effect of temperature and pressure on product distribution

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Abstract

The hydropyrolysis of a Turkish lignite (Tunçbilek) in a swept fixed bed reactor connected with a thermo-balance was performed at a heating rate of 3 °C/min up to 950 °C under 0.5 MPa, 1 MPa and 10 MPa hydrogen pressures. The formation rates of gaseous hydrocarbons, carbon oxides, water and tar were determined. The difference between the weight loss due to tar formation of the non-condensable total and the weight loss of the sample recorded continuously with the thermo-balance showed the corresponding curve of tar formation rate as a function of temperature. It was shown that the total conversion and the formation rate of the products during hydropyrolysis could be influenced by varying the pressure. On the other hand, the volatile matter evolved during pyrolysis was substantially increased in the presence of hydrogen and especially when elevated hydrogen pressure was used.

Keywords: Lignite; Hydropyrolysis; Product yield

1. Introduction

Coal is a solid with a high carbon content and a hydrogen content of typically around 5% and never more than 6%. Coal may be used to produce liquid chemicals, fuels and gaseous products

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either by removal of carbon or by the addition of hydrogen, directly or indirectly. The first approach is usually known as carbonization or pyrolysis and the second as liquefaction. When coal or lignite is heated, it undergoes a series of chemical and physical reactions, which are included under the term 'pyrolysis'. Hydrogen rich volatile matter is evolved and tars, phenols, carbon oxides and hydrocarbon gases are released during pyrolysis. Coal pyrolysis plays an important role in coal science and coal processing. The yield and properties of the products and their formation rates during thermal treatment give an insight into the reaction behavior and the chemical and physical structural properties of the coal [1]. Furthermore, pyrolysis is a process for the production of premium liquids and gases by the application of heat to the coal.

The volatile matter evolved during pyrolysis is substantially increased in the presence of hydrogen and especially when elevated hydrogen pressures are used. This so-called hydropyrolysis involves the reaction of coal with hydrogen at temperatures and pressures similar to those used in other coal liquefaction processes [2,3]. Recently, pyrolysis and hydropyrolysis processing technologies have received more attention because they are not only an important intermediate stage in gasification, combustion and liquefaction, but also they are simple and effective methods for clean conversion of coals [4–8]. Hydropyrolysis is potentially an attractive route for production of liquid chemicals and fuels from coals. Historically, hydropyrolysis has received more attention in relation to coal liquefaction and gasification [9].

Turkey has both hard coal and lignite deposits. The hard coal is mostly located in the western part of the country in the Zonguldak Basin, which has more than 700 million metric tons of workable reserves, about 80% of which can be coked. Lignite deposits are widespread and plentiful. Reserves are estimated at more than eight billion metric tons (7th largest in the world), most of which are economically mineable although only about 7% has a heat content of more than 3000 kcal/kg. Turkey has little oil and gas of its own but has a much larger, and steadily increasing, demand. Nearly 75% of the indigenous lignite is used to produce electricity in thermal power plants. An alternative might be to use a mild pyrolysis process to upgrade these lignites although current process economics is not attractive. Owing to a shortage of oil and gas fuels, methods of deriving liquids, gases and chemical feedstocks from Turkish lignites are under intensive study.

In continuation of a previous work [10], the aim of this study was to investigate the effects of the reactive gas atmosphere, temperature and pressure on the course and products of a Turkish lignite and to detect the detailed structure of the product formation curves during lignite hydropyrolysis.

2. Experimental

Detection of the detailed structure of the product formation curves during coal pyrolysis is only possible from experiments that use low heating rates [11]. Therefore, the hydropyrolysis reactions were investigated in a thermo-balance equipment with a non-isothermal heating technique. Because of the relatively low heating rate of several °C/min in the thermo-balance, the volatiles are slowly released from the coal sample and continuous transport by a carrier gas flow to an analysis system becomes possible. Thus, a continuous analysis of the products and detection of the product formation as a function of rising temperature in one experimental run with the same sample is possible.