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DESULFURIZATION OF HETEROCYCLIC SULFUR IN JAMBI COAL USING POTASSIUM CARBONATE-ETHYLENE GLYCOL DEEP EUTECTIC SOLVENT

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ABSTRACT

Coal combustion releases SO2, contributing to environmental pollution. Therefore, effective desulfurization is essential to break the strong C-S bonds in heterocyclic sulfur coal. This study is unique because desulfurization was conducted on solid coal with its complex and heterogeneous structure. Most previous studies have focused on liquid fuels, in which C-S bonds are easier to break compared to those in solid coal. Potassium carbonate-ethylene glycol (PC-EG) as Deep Eutectic Solvent (DES) is used as a replacement for volatile and flammable organic solvents. Physicochemical analysis showed that molar ratios of 1:8, 1:12, 1:16, and 1:19 reached eutectic points and remained in liquid form, as confirmed by DSC and phase diagram analysis. FTIR analysis confirmed the presence of H-bonding, but the interaction reduced as molar ratio increased. Increasing molar ratios and temperatures decreased viscosity, pH, and density while increased ionic conductivity. Thermal analysis showed that the mixtures remained stable between 110-160 °C. The findings indicate the optimal use of PC-EG at suitable molar ratios and temperatures to improve desulfurization performance. Then, Jambi coal was pretreated with PC-EG mixtures under various molar ratios, temperatures, and time. RSM-CCD was employed to minimize the number of experimental runs while identifying optimal parameters. The optimal parameters were identified as 1:16 molar ratio, 40 °C temperature, and 60 min extraction time, achieving 65.77% heterocyclic sulfur removal. ANOVA analysis revealed that extraction time had the greatest impact, followed by molar ratio and temperature. The findings suggest that other DESs can perform similarly to DES-16 with sufficient processing time. Viscosity and ionic conductivity also play important roles in desulfurization performance. Ultimate analysis indicated a reduction in carbon (57.43%), hydrogen (4.67%)), nitrogen (0.74%>), and total sulfur (1.28%) after desulfurization. The reduction in sulfur content was consistent with the findings from FTIR and XPS analyses. However, oxygen (35.89%>) content increased due to the formation of sulfoxides and sulfones. Proximate analysis demonstrates lower volatile matter (VM) (40.12%>) and ash contents (5.73%) with higher fixed carbon (FC) (54.15%). The VM and FC contents produce higher fuel ratio (1.35), indicating more efficient combustion, longer burning time, reduced smoke, and increased calorific value (CV). However, CV (20.90 MJ/kg) decreased due to decrease in carbon and sulfur content. TG analysis revealed slower weight loss, indicating improved thermal stability and structural integrity of treated coal. GCMS analysis of the model sulfur compounds confirmed the extraction and transformation of heterocyclic sulfur during desulfurization. The reaction mechanism was elucidated, highlighting the interactions between carboxylate ions in PC-EG and the sulfur species. The experiments were conducted on a small scale under controlled laboratory conditions, which do not accurately represent the high-temperature environments of industrial coal desulfurization. This limitation may affect the applicability of the findings to large-scale or industrial desulfurization processes. Additionally, the study did not assess solvent reusability, highlighting another limitation of the research at this scale.

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CHAPTER 1
INTRODUCTION

This chapter presents the background and rationale for investigating coal desulfurization using a potassium carbonate-ethylene glycol (PC-EG) as a Deep Eutectic Solvent. The problem statement establishes the scope of the study and clearly outlines the specific research objectives. The chapter also emphasizes the significance and relevance of the study, highlighting its potential effect on coal desulfurization technologies.

1.1 Research Background

The primary challenge in coal desulfurization is the effective removal of sulfur-containing compounds, especially those in heterocyclic forms [1]. Heterocyclic sulfur compounds, such as benzothiophene, are strongly bonded to the coal macromolecular structure, resulting in significant challenges for extraction [2]. During combustion, sulfur in coal is released as sulfur dioxide (SO2), which then reacts with water and oxygen in the atmosphere to form acid rain. This phenomenon has harmful effects on the environment [1, 3]. Moreover, high concentration of aromatic compounds reduces fuel quality, highlighting the need to separate heteroaromatic chemicals from aliphatic components [2].

Traditional hydrodesulfurization (HDS) method are effective in removing sulfur from aliphatic hydrocarbons. However, the removal of heterocyclic sulfur such as thiophene, benzothiophene, and their derivatives remains challenging due to steric hindrance. Furthermore, the HDS process operates under high temperatures and pressures, which can lead to the breakdown of coal macromolecular structure and increase operational costs. To address these limitations, combining extraction with oxidative desulfurization (EODS) has been identified as a cost-effective alternative to traditional HDS [4]. EODS operates under mild conditions and employs environmentally friendly extractants and catalysts to remove aromatic sulfur compounds [5]. However, one drawback of the EODS method is its reliance on organic solvents, which raise concerns regarding safety and environmental impact. These issues have driven the search for greener alternatives, such as Deep Eutectic Solvents (DESs)