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Short communication

Thermal Stability and Decomposition of Synthetic Oils in Medium-Temperature CSP Systems

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Abstract

This short communication investigates the thermal stability and decomposition behavior of synthetic oils used in medium-temperature concentrated solar power (CSP) systems. We present new experimental data on the thermal degradation of biphenyl/diphenyl oxide mixtures under CSP-relevant conditions. Our findings reveal a critical temperature threshold for accelerated decomposition and identify key degradation products. These results have significant implications for optimizing heat transfer fluid (HTF) selection and maintenance strategies in CSP plants, potentially extending operational lifetimes and improving overall system efficiency.

Keywords: Concentrated Solar Power (CSP), Thermal Stability and Decomposition of Synthetic Oils, Medium-Temperature CSP Systems

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Introduction

Synthetic oils, particularly biphenyl/diphenyl oxide mixtures, are widely used as heat transfer fluids (HTFs) in medium-temperature concentrated solar power (CSP) systems operating between 150°C and 400°C [1-14]. The thermal stability of these fluids is crucial for maintaining system efficiency and minimizing maintenance costs. However, the long-term behavior of synthetic oils under CSP operating conditions remains incompletely understood [15-25]. This study aims to elucidate the thermal stability limits and decomposition mechanisms of a common synthetic oil mixture used in CSP applications.

Methods:

We subjected a commercial biphenyl/diphenyl oxide mixture (Therminol VP-1) to accelerated thermal aging tests using a custom-built high-temperature, high-pressure reactor. Samples were heated to temperatures ranging from 300°C to 450°C for periods of 100, 500, and 1000 hours under an inert atmosphere. Chemical composition changes were analyzed using gas chromatography-mass spectrometry (GC-MS) and Fourier-transform infrared spectroscopy (FTIR).

Thermophysical properties were measured using differential scanning calorimetry (DSC) and a transient hot-wire thermal conductivity analyzer.

Results and Discussion:

Our experiments revealed a critical temperature threshold of approximately 425°C, above which the rate of thermal decomposition increased dramatically (Figure 1). The primary degradation products identified were phenol, benzene, and various alkylated aromatics, suggesting a complex series of cracking and rearrangement reactions.

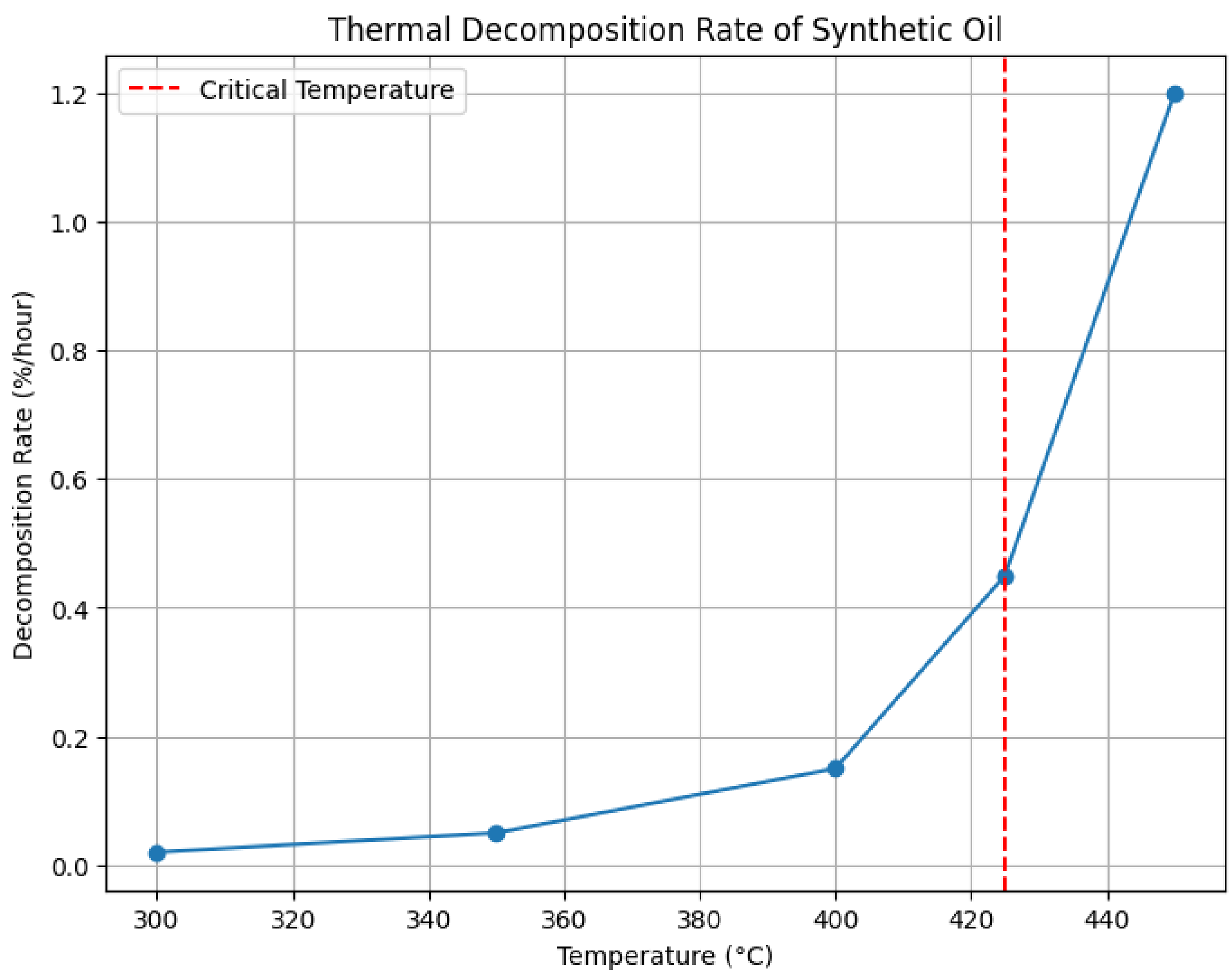

Figure 1: Thermal decomposition rate of synthetic oil as a function of temperature, showing a critical threshold at 425°C.

The formation of these degradation products correlated with a decrease in thermal conductivity (up to 12% at 450°C after 1000 hours) and an increase in viscosity (up to 35% under the same conditions). These changes in thermophysical properties have direct implications for heat transfer efficiency in CSP systems.

Interestingly, we observed a synergistic effect between thermal and oxidative degradation. Trace amounts of oxygen (< 50 ppm) accelerated the decomposition rate by a factor of 1.5-2, emphasizing the importance of maintaining an oxygen-free environment in CSP heat transfer systems.

Conclusion:

This study provides new insights into the thermal stability limits and decomposition mechanisms of synthetic oils used in medium-temperature CSP systems. The identification of a critical temperature threshold at 425°C and the characterization of key degradation products offer valuable guidance for CSP plant operators. These findings suggest that operating temperatures should be carefully controlled to remain below this threshold, potentially through improved temperature monitoring and control systems.

Future research should focus on developing novel additives to enhance thermal stability and investigating alternative HTF formulations that maintain performance at higher temperatures. Additionally, the synergistic effect of thermal and oxidative degradation warrants further investigation to develop more robust oxygen management strategies in CSP plants.

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