СЕКЦІЯ

ЕНЕРГОЕФЕКТИВНІСТЬ ТА ЕНЕРГОМЕНЕДЖМЕНТ ЗАСОБІВ ТРАНСПОРТУ І ІНФРАСТРУКТУРИ

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ANALYTICAL COMPARISON OF SOLID FUEL COMBUSTION EFFICIENCY IN A PULSATING BED

АНАЛІТИЧНЕ ПОРІВНЯННЯ ЕФЕКТИВНОСТІ СПАЛЮВАННЯ ТВЕРДОГО ПАЛИВА В ПУЛЬСУЮЧОМУ ШАРІ

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The combustion efficiency of solid fuels in a pulsating bed is a critical factor in optimizing energy generation and minimizing environmental impact. Pulsating combustion technology introduces periodic pressure and velocity fluctuations into the combustion process, enhancing mixing, heat transfer, and fuel burnout efficiency. This study presents an analytical comparison of solid fuel combustion efficiency in a pulsating bed, focusing on key parameters such as flame stability, heat transfer dynamics, pollutant formation, and overall thermodynamic performance. The research examines the influence of pulsation frequency, fuel particle size, and excess air ratio on combustion characteristics. The advantages of pulsating bed combustion, including improved thermal efficiency, reduced emissions, and enhanced fuel flexibility, are explored in comparison to conventional fluidized and fixed-bed combustion systems. The findings provide insights into optimizing pulsating combustion technology for various industrial applications and sustainable energy production [1].

The fundamental mechanism of pulsating combustion is based on the interaction between acoustic waves and reactive gas flows. The periodic compression and expansion of gases lead to improved fuel atomization and mixing with oxygen, resulting in higher combustion completeness and more uniform temperature distribution. Additionally, the increased turbulence promotes rapid heat release, enhancing thermal efficiency while reducing unburned carbon losses [2]. A key advantage of pulsating bed combustion is its ability to operate efficiently across a wide range of solid fuels, including low-grade biomass, coal, and municipal waste. The dynamic nature of the airflow prevents fuel agglomeration, ensuring better particle dispersion and prolonged residence time within the combustion zone. This extended exposure to high temperatures enables more complete oxidation of carbonaceous materials, reducing the formation of soot and particulate emissions.

The study analyzes how pulsation frequency influences combustion performance. Higher pulsation frequencies tend to increase turbulence intensity, enhancing mixing and heat transfer, but may also lead to excessive entrainment of fine fuel particles, reducing retention time and affecting burnout efficiency. Conversely, lower frequencies may improve fuel retention but can result in localized high-temperature zones, increasing the risk of nitrogen oxide (NOx) formation. Identifying the optimal pulsation frequency for different fuel types is critical for maximizing efficiency while minimizing emissions [3].

Another important factor is the excess air ratio, which affects both combustion completeness and thermal losses. In a pulsating system, the intermittent introduction of combustion air allows for better control of the oxygen supply, reducing heat loss due to excess air while maintaining adequate oxidation conditions. Unlike conventional combustion systems, where excessive air can lead to heat dissipation, pulsating combustion enables better utilization of available thermal energy by intermittently exposing fuel particles to oxygen-rich and oxygen-lean conditions, promoting staged combustion [4].

Heat transfer in a pulsating bed occurs primarily through convection and radiation, with pulsating flow conditions enhancing convective heat exchange between the hot gases and surrounding surfaces. The increased turbulence accelerates the transport of thermal energy to the furnace walls and heat exchangers, improving overall system efficiency. Compared to conventional fluidized or fixed-bed combustion, pulsating combustion achieves higher heat transfer rates while operating at lower excess air levels, reducing overall energy losses [5].

A comparative analysis with other combustion technologies, such as fluidized bed and fixed-bed combustion, reveals significant advantages of pulsating bed combustion in terms of efficiency and environmental performance. Fixed-bed combustion, while simple and widely used, suffers from uneven fuel distribution and localized hightemperature regions, leading to incomplete combustion and high pollutant emissions. Fluidized bed combustion, on the other hand, improves mixing and fuel utilization but requires precise control of fluidization velocity to avoid excessive fuel loss. Pulsating combustion bridges these gaps by combining the uniform fuel dispersion benefits of fluidized systems with the enhanced mixing and heat transfer effects of pulsation, resulting in higher efficiency and lower emissions.

The analytical comparison of solid fuel combustion efficiency in a pulsating bed highlights the superior performance of this technology in terms of fuel utilization, heat transfer, and emissions reduction. The oscillatory motion of the combustion process enhances fuel-air mixing, increases turbulence, and prolongs fuel residence time, leading to higher combustion completeness and lower unburned carbon losses. Compared to conventional fixed and fluidized bed systems, pulsating combustion demonstrates improved thermal efficiency and better control over pollutant formation.

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ANALYSIS OF COMBUSTION OF LOW-GRADE FUEL IN A FLUIDIZED BED

АНАЛІЗ СПАЛЮВАННЯ НИЗЬКОЯКІСНОГО ПАЛИВА У КИПЛЯЧОМУ ШАРІ

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The combustion of low-grade fuels in fluidized bed technology represents a promising approach for improving energy utilization while reducing emissions. Low-grade fuels, such as lignite, biomass residues, and industrial waste, often have high moisture and ash content, making their combustion less efficient in conventional systems. Fluidized bed combustion (FBC) offers a solution by ensuring improved fuel-air mixing, extended particle residence time, and uniform temperature distribution, which enhances combustion efficiency. This study analyzes the thermodynamic and combustion characteristics of low-grade fuels in a fluidized bed, focusing on heat transfer mechanisms, fuel conversion efficiency, and emission control. The impact of fluidization velocity, bed material properties, and excess air ratio on combustion performance is examined. The results contribute to optimizing fluidized bed operation for better fuel utilization, lower environmental impact, and enhanced energy recovery from low-quality fuels [1].