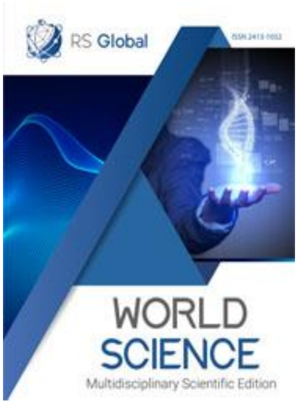

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editorial_office@rsglobal.pl

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PROSPECTS OF LOW-EMISSION INNOVATIVE TECHNOLOGY FOR EFFICIENT USE OF LOCAL FUEL

Nodar Kevkhishvili
Ph.D., Professor at Georgian Technical University

Tengiz Jishkariani
Ph.D., Professor at Georgian Technical University

Khatia Arabidze
Ph.D., Professor at Georgian Technical University

Nikoloz Javshanashvili
Ph.D., Visiting Professor at Georgian Technical University

ABSTRACT

This article addresses the global problem and proposes an innovative and highly efficient solution, particularly, the combustion process using the High-Temperature Fluidized Bed Technology. Many scrap tires and biomass waste are generated worldwide in every specific country or region. Removing such waste is a serious problem as its disposal in the landfill is prohibited. The best solution to this challenge is the eco-friendly utilization of such waste as a local fuel. Georgian Technical University (GTU) professors conducted a theoretical study describing the relationship between the pollutants emitted and combustion temperature, which was practically tested and approved using the created 2 MW capacity device (Patent P6828, 2018-03-20) working on the High-Temperature Fluidized Bed Technology, which fully differs from the commonly introduced Low-Temperature Circulative Fluidized Bed Technology. The most interesting confirmation is that even in the case of biomass and scrap tire mixture usage, the GHG emissions are less compared to Natural Gas combustion. Recently a 5 MW capacity combustion device was for a particular business purpose. Both creatures were recognized and awarded by the Association of Energy Engineers of USA (AEE) and Energy Globe contest in 2021 and by the AEE in May 2024.

2 MW and 5 MW capacity devices with their patent and awards

KEYWORDS

Fluidized Bed, Energy Efficiency, Biomass, GHG Emissions, Waste-to-Energy

CITATION

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Introduction

The disposal of scrap tires is a serious environmental problem also, there are case studies that argue against the combustion of tires and vice versa, Waste-to-Energy (WTE) technologies are more environmentally friendly than mechanical recycling technologies. Numerous laboratory studies have been conducted on the pyrolysis and gasification of waste tires but few industrial-scale recycling plants exist due to the current practice that is related to the Low-Temperature Circulative Fluidized Bed Technology which is less effective compared to the High-Temperature one that leads to unsolved problems such as interruption of the combustion process, slag removal, etc. Our innovative approach and created combustion devices allowed proceed of the High-Temperature Fluidized Bed that was impossible before.

Combustion in the Fluidized Bed

The Fluidized Bed Combustion furnaces have attracted the attention of specialists as an effective means of utilization of cheap local low-quality solid fuels with high profitability. Later, other advantages of coal combustion in the Fluidized Bed were discovered, related to the possibility of reducing emissions of sulfur and nitrogen oxides into the atmosphere.

The main advantage of the Fluidized Bed is the possibility of direct purification of combustion products in the chamber itself, which ensures high environmental standards. This is primarily related to sulfur oxides. In this regard, additives of limestone, lime, and dolomite are added into the Fluidized Bed, which binds the sulfur contained in the coal. Limestone in the fire first turns into lime, which reacts with sulfur oxides to form calcium sulfate. The degree of sulfur binding is very high (reaches 90%) and the residual content of sulfur oxides in flue gases does not exceed 200-400 mg/m^3. The degree of sulfur binding is determined by the following parameters [1;2]:

- Molar ratio to Ca/S (usually about 2-3);
- Temperature (optimal temperature 800-900 ^{o}C).

As a result of research carried out at the Georgian Technical University (GTU), an innovative combustion device was created using the High-Temperature Fluidized Bed Combustion Technology, ensuring efficient combustion of various types of fuel. The High-Temperature Fluidized Bed Technology implemented and proposed at this stage (Patent P6828, 20.03.2018) in comparison with the Low-Temperature Circulative Fluidized Bed combustion technology currently widely used in the world, has several advantages, namely:

- Does not require the presence of an inert mass in the Fluidized Bed;
- Does not require limiting the top temperature limit to 900-950 ^{0}C, which facilitates its automatic control;
- The concentration of fuel in the combustion chamber is not limited, therefore a higher thermal load is achieved in the combustion chamber (Q_F = 20-22 MW/m^2) than in a circulative fluidized bed Q_F = 6-8. MW/m^2;
- Has a wide range of power adjustment-control (30-100%);

The combustion device works as follows:

The feeding air supplied by the fan enters the channel, from where it has an outlet only through the gap between the grille and the inner surface of the directional cylinder. At the same time, the grille performs rotational movement with the shaft. But the grille is tilted at a certain angle to the horizon (5-10 degrees). Consequently, during sliding the grille inside the directional cylinder, the gap between them performs an oscillating movement in the vertical plane which causes a pulsation of the feeding air entering the combustion chamber in the vertical direction and therefore, to the fluidized bed. Along with the feeding air, the fuel also moves into the fluidized bed, which ensures the high intensity and stability of the combustion process. At the same time, the pulsation of the feed air carried out by the grille with the monotonically decreasing acceleration amplitude of the vertical vibration movement ensures intensive mixing of the fluidized bed and its equalization in the entire volume of the combustion chamber [3].

Due to the absence of a horizontal stabilizer of vibration in the fluidized bed, the presence of areas with different hydrodynamic resistance is excluded. Fluidized bed with the same hydrodynamic indicators in the entire volume ensures high intensity and stability of the combustion process, using the optimal amount of feed air without losses.

The disc has possibility of movement in both the horizontal and vertical planes also, its acceleration amplitude is constant in the horizontal plane, and monotonically decreases in the vertical plane, with the relative acceleration of the vibration

$$K = \frac{A \cdot W^2}{g} > 1$$

where K - is the relative acceleration of vibration;
A - is the vibration amplitude, m;
g - gravitational acceleration, m.s^{-2};
$W = 2 \cdot \pi \cdot f$ - is the angular speed of vibration, rad.s^{-1};
f - vibration frequency, s^{-1}.

A directional cylinder is rigidly attached to the combustion chamber. Inside the cylinder is inserted a sliding grille, which is an elliptic disc inclined 5-10 degrees to the horizon.

Combustion device with the fluidized bed burner is very efficient and almost irreplaceable for the implementation of the combustion process of large structural heterogeneity, fine-fraction solid heating.

The measured concentrations of emissions of harmful substances into the atmosphere as a result of combustion of alternative fuels in parallel with natural gas, which is used in the second stage of combustion (40-50%), are shown in Table 1.

Table 1. Technical characteristics of alternative fuels

№	Fluidized Bed Technology	Biomass	Tire chips+Biomass	Tire chips	Natural gas
1	Calorific value, J/kg	20 000	23 000	27 000	35 000
2	Calorific value, kWh/kg	5,56	6.28	7,50	9,70
3	Emission factor, kg CO_2/kWh	0,00	0,172	0,23	0,202
4	SO_2 , mg/nm^3	-	116	200	-
5	NO_2 , mg/nm^3	224	138	290	730

Table 1 shows that greenhouse gas emissions will be zero in the case of utilization of renewable biomass, and in the case of combined fuel (Tire Chips + Biomass) greenhouse gas emissions will be significantly reduced compared to combustion of natural gas.

Firing Processes in the Combustion Chamber

In the combustion chamber, two-stage combustion is used to reduce the formation of fuel oxides. At the first stage, pulsation liquefaction and gasification of the fuel occur at a temperature of less than 900 ^{o}C. Due to low temperature, little thermal nitrogen oxides are formed in the Fluidized Bed. In this case, only part of the air required for the complete combustion of the fuel is supplied to the furnace at the first stage, subsequent portions of air are supplied at the second stage. As a result of the two processes, the concentration of nitrogen oxides in flue gases usually does not exceed 290 mg/m^3. At the second stage, complete combustion of gaseous products occurs during co-combustion with gaseous fuel (40-50% ratio) at a temperature of 1200 ^{o}C.

In addition to environmental benefits, combustion in the Fluidized Bed has other advantages. As noted, in the Fluidized Bed furnaces the gas flow rate relative to solid particles is very high, which contributes to the intensification of the combustion process. As a result, the thermal efficiency of the Fluidized Bed reaches high values - up to 22 MW/m^2 per unit of Fluidized Bed area in the furnace.

Conclusions

- The harmful emissions are significantly reduced due to the second stage combustion process, as shown in Table 1;
- An inert mass for the combustion process is not required;
- Combustion temperature at the first stage ranges from 900 ^{0}C to 950 ^{0}C;
- The specific capacity in the combustion chamber achieves of Q_F = 20-22 MW/m^2;

Result

The created device approved that Fluidized Bed Combustion Technology is the most effective way to utilize scrap tire and biomass.

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