Research on the detonation cell size of biogas-oxidizer mixtures in the context of rotating detonation

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ABSTRACT

Global warming and climate changes cause ever growing concerns in the international community. This in turn is reflected in growing research effort in the topic of alternative and renewable fuels and energy production with low or no impact on the environment. At the same time energy is vital for worldwide development and improving of people's living standard. This standard is high in countries with high industrial growth, but for this growth energy is needed and most of it is acquired from fossil fuels (coal, oil and natural gas) [1]. Those facts lead to the conclusion that the world is in dire need of alternative and renewable energy sources to be able to reduce the global emissions of carbon dioxide and fulfill the international agreements. There are many different solutions proposed by the scientific community, one of them is to utilize biogas as a replacement of fossil fuels. Biogas is a mixture consisting mainly of CH_4 and CO_2 [2] with an addition of different contaminants. The composition of the biogas heavily depends on the source from which it was produced, the typical values of volume percentage in the biogas ranges from 35 to 70 for CH_4 and 15-50 for CO_2 [3,4]. Biogas is seen as a promising, alternative source of energy for a number of reasons. One is that due to being produced from biomass the net balance of CO_2 emitted into the atmosphere is equal to 0 or almost 0. What is more, using the bio-wastes as energy sources is more cost-effective than producing a new biomass [5]. Biogas, as well as other eco-friendly biofuels, is also easily storable and as such is more reliable and stable source of energy than solar and wind sources that suffer from unreliability due to their dependence on the weather conditions [6]. Despite having those advantages, biogas has also some drawbacks. The most important one is its Lower Heating Value (LHV) that ranges between 16 MJ/Nm^3 and 23 MJ/Nm^3 [4,6] which compared to the LHV of natural gas(33.5 [6] or 39 MJ/Nm^3 [4]) or methane (35.8MJ/Nm^3 [6]) is significantly lower. To keep the efficiency at an acceptable level while firing biogas in a gas turbine it requires increased fuel flow [7]. However, this in turn leads to a decrease of a compressor surge margin [7–9] and overheating of the turbine blades [9,10] limiting their useful life. To overcome these problems we propose burning the biogas in a detonative mode instead of the deflagrative that is commonly used nowadays. The main advantage of the detonation combustion is its higher thermal efficiency [11,12] when compared to the isobaric or isochoric cycle. It can also burn in a wide variety of equivalence ratios from lean to rich mixtures. Especially interesting is the detonation of lean mixtures as the temperature of such process will be lower than of stoichiometric mixture which solves the problem with turbine overheating and also assures lower NO_x emissions.

In this presentation we show the undergoing effort of building an experimental test stand for taking the measurements of the detonation cell size of biogas-oxidizer mixtures. The cell size is a basic detonation parameter which can be used for determining other dynamic parameters of multiheaded detonations of a given mixture [13]. It is especially important for the proper design of the Rotating Detonation Engine because to achieve stable detonation in the chamber the width of the chamber must be bigger than the detonation cell [14]. It is then obvious that thorough research of this topic is very important in the context of future plans for designing gas turbines utilizing rotating detonation combustion chamber fueled by a biogas.

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