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THE APPLICATION OF PYROLYSIS GAS AS A FUEL FOR GAS TURBINE ENGINES FOR ELECTRICITY GENERATION

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Abstract. Purpose: The purpose of this article is to show the opportunities of application of the pyrolysis gas as a fuel for gas turbine power plants based on decommissioned gas turbine engines, including those from aircraft – either turboprop or turboshaft, or both, and also those used on ground vehicles such as tanks and marine engines as well. Methods: The article describes the technology of pyrolysis of different materials for obtaining pyrolysis gas and its further application as a fuel for internal combustion engines was developed in the end of XIX century and was successfully applied for automobile, marine and railway locomotive piston engines till the mid XX century when large oil reservoirs were discovered all around the World. Results: the current research not only proves that there exists an economic benefit of application of pyrolysis technology even at nowadays, but also an ecological one, allowing getting rid of garbage Discussion: The proposed examples of successful pyrolysis technology application can be a good basis for further research of transferring modern engines to the pyrolysis gas fuels.

Keywords: pyrolysis, gas turbine engines, gas generators, pyrolysis gas, alternative fuels, electricity generating, continuing lifecycle.

1. Introduction

The reserves of World's fossil fuels and other non-restorable burning materials, such as coal and turf are estimated to be finished in maximum 400 years from nowadays. The production of oil-based household and industrial items is not only continuing, but also rapidly growing despite many attempts to reduce their manufacturing. This means that when the natural resources will be essentially mined, the humanity will still have an opportunity to get a source of fuel – the trash. The household & industrial trash can undergo the process named the pyrolysis, also known as cracking. This gas consists of carbon and hydrogen, their compounds and other elements. The gas is flammable and can be used as an additional fuel to the currently burning materials and as a separate kind of fuel as well. The heat capacity and other thermodynamic properties of pyrolysis gas depend of the source that is being cracked in the special device known as the pyrolysis generator.

The pyrolysis gas is actually a very well-known and well-studied type of fuel itself. The first cases of usage of pyrolysis gas as a fuel for internal combustion engines appeared in the late 19th century, as soon as these engines have been invented in their modern versions and began to substitute widely spread steam engines.

2. Analysis of the research and publications

A great masterpiece research on solid fuels gas generating was published in 2010 in the Saint Petersburg, Russian Federation [1]. This work includes quite a detailed historic overview of pyrolysis invention as a physical phenomenon, the first attempts of usage of pyrolysis gas in industry and general basic information that is required to understand the technology of the pyrolysis. However, basic information is followed by a detailed description of different existing types of gas generators with explanation of application of each type depending on the task it is supposed to do. The author also describes two other important issues: the industrial application of the pyrolysis gas generators and also a few methods of cleaning the pyrolysis gas from non-flammable additives – the dust, resins, oxides, etc.

Another research [2] is dedicated to the studying of the biomass burning. The authors explain step by step what the biomass is, what are the ways to burn it. They bring examples of different furnaces design and ways to calculate their parameters depending on the desired biomass to be burned. The research contains useful examples of calculations of main thermodynamic parameters of a furnace, which will be very useful for my future project.

Also, the current article is a continuation of research work on pyrolysis gas by I.Obodovskyi [3], but it is a much more detailed overview of pyrolysis technology comparing to earlier published theses.

3. Problem statement

The pyrolysis technology is considered outdated nowadays and is usually described as a historic technology along with steam one. For the past 70 years pyrolysis-powered vehicles and power plants have been constructed by enthusiasts only, while the amount of household and industrial garbage, especially one consisting of oil-based residues, has been rapidly increasing to the level of ecology disaster all around the World and in Ukraine as well.

4. Problem Solution

4.1. Historic overview

The two World wars that were full of modern military equipment have also revealed the fact that the mobility of all vehicles depends from the presence of fossil fuels and that whole armies either get stuck or lose resources due to transport collapse in case of oil absence. Moreover, oil sources sometimes may be located either far away from front line or at the enemy territories. Thus, the idea of usage of alternative fuels has become popular starting from WWI and has been fully technologically implemented during the WWII. Pyrolysis powered trucks such as one on the fig. 1, were real work horses of the war, providing supplies operations for Soviet, American, British, German, French armed forces. [4] Pyrolysis powered cars remained a popular kind of civil transport as well until 1960-s, when giant oil sources were discovered in USSR, UAE, Iraq, Iran, etc.

4.2. The explanation of the idea

The novity of the proposed research is exactly the refurbishing of either turboprop or turboshaft gas turbine engines so that they could use pyrolysis gas as a fuel instead of fossil fuels.

The idea of conversion of a gas turbine engine to the pyrolysis gas instead of conventional fossil fuels requires the creation of a new design of its combustion chamber primarily. The reason for that is the fact that the pyrolysis gas, consisting mostly of flammable gases such as carbon monoxide and hydrogen sometimes, has lower burning parameters comparing to traditional gas turbine fuel - the kerosene. Therefore, it is required to evaluate two main set of data - the properties of pyrolysis gas and parameters of any existing gas turbine engine.

The pyrolysis gas consists of mostly hydrogen and carbon monoxide depending on its source. [5] The typical fuel for pyrolysis generators is either charcoal, or pre-dried wood or wet wood, or organic water-based food & beverage production residues. When the point is about usage of wood as a fuel, the obtained carbon monoxide has a calorific capacity that is on average 8 times lower comparing to the conventional jet fuel. The application of hydrogen requires its purification due to a well-known fact that the pure hydrogen does not detonate unlike the hydrogen mixed with oxygen. Thus, the operation of pyrolysis generator working on organic water-based food & beverage production residues requires additional hydrogen equipment. [6]

Such a relatively lower rate of calorific capacity requires the modification of engine gas chamber sizes so that the correct proportion of air & fuel will be obtained there in order to provide stable Brayton cycle. [7]

First of all, it is required to analyze the potential sources of pyrolysis gas that will be burned in the pyrolysis generator, the scheme of which is presented on fig. 2. Each spring in Ukraine the workers of city service enterprises perform the cutting of dried trees and branches all around the country.[8] Each autumn there appear lots of farming industry residues, such as leaves, culms, etc. The pyrolysis gas generator having enough height will be able to dry the fluids out of biological substances and crack them to the carbon monoxide. Also, organic wastes from various food industry enterprises can be used as a pyrolysis gas source. The amount of these wastes will provide the sufficient amount of flammable pyrolysis gas for the gas turbine engine operation. Secondly, it is necessary to choose the electric generator taking into a count that fact that it has to generate electric power during the range of operational revolutions per minute equal to ±300-400 RPM due to the fact that different sources of pyrolysis gas might be used during the operation day, providing either more or less concentrated pyrolysis gas. However, this cannot be considered a problem since all aircraft gas turbine engines are usually equipped with special reducers that give the constatnt output RPM allowing a generator to produce the same amounts of energy.

Third, it is required to choose such type of basic gas turbine engine that will allow to rebuild its combustion chamber with least possible modifications and, therefore, financial charges. A good example of gas turbine engine that is suitable for modification is the GTD-350 engine from the Mi-2 helicopter (presented on fig. 3) or its western analogue - the Rolls Royce RR500 engine. There were produced more than 11000 Izotov GTD-350 engines [9] and due to their high fuel consumption and wear out of Mi-2 helicopters' airframe, lots of them are not used on aircraft anymore, but that means that they are available to be modified for the current goal. These engines have a very unusual design – their combustion chamber is located in the aft part of the engine and the air is supplied via two forward air ducts that surround the turbines, while the hot air from combustion chamber changes its vector after burning there and goes to the turbine section, unlike to most popular design where combustion chamber is located just behind the air compressor and is followed by turbines. Since the combustion chamber of GTD-350 is located in the aft part, it is easily removable and accessible and what is the most important can be easily replaced by the enlarged one so that it will maintain the correct air-to-fuel ratio, which is equal to approximately 20:1 for most types of fuels.

Fourth, it is required to design the modified enlarged gas chamber in such way that the mix of air and flammable pyrolysis gas will be burned in such way that the burning gas mix will transfer its power to the turbine. [10]

For that, a study of gas dynamics of the enlarged combustion chamber is required to do as well. It might be that the new combustion chamber would have not a cylindrical, but spherical shape so that the enlarged required volume of chamber will need the minimum geometrical sizes enlargement.

Finally, it is required to design a new combustion chamber so that it could use conventional fossil fuels in order to perform various maintenance checks of the engine and other power plant parts and also to make the engine start up faster in order to spend less pyrolysis gas for this purpose.

5. Conclusions

To sum up, it can be stated that the opportunity of using gas turbine engines will allow to use decommissioned aircraft/marine/land vehicle gas turbine engines as generators, eliminating the necessity of decommissioning them, spending finances on this process. Instead, all outdated engines' lifetime will be continued for the purposes of usage on stationary gas turbine power plants.

Moreover, the finances spent on converting these engines to power plants can bring profit from electricity sales, while outdated engines decommissioning process does not bring profit at all.

The gas turbine engine gives relatively higher power than any piston engine, provides stable working cycle and therefore less vibrations and noise pollution to the industrial site and surrounding cities where they will be located.

The main positive effect of application of gas turbine pyrolysis power plants is that the house hold & industrial rubbish will not require large territories for its long-term storage. It will not be simply burned on conventional heat power plants in order to boil water. Instead, the wastes disposal will give direct electric energy – a vital resource for any type of commercial and private users.

Fig. 1. The “Uralzis” WWII era Soviet pyrolysis powered truck

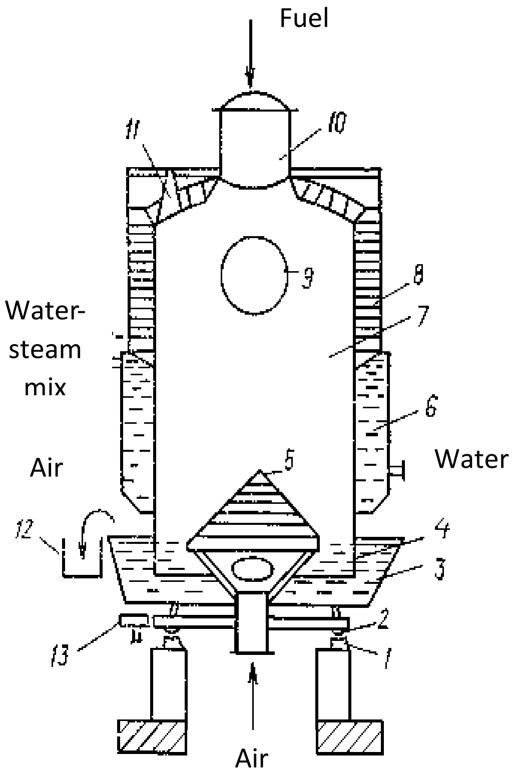

Fig. 2. The scheme of a typical pyrolysis gas generator
1 — railway basement,
2 — roller,
3 — bowl;
4 — «apron»,
5 — grating;
6 — water cover,
7 — shaft,
8 — coating,
9 — gas draining orifice,
10 — fuel loading device,
11 — poking orifice;
12 — residues container,
13 — drive.

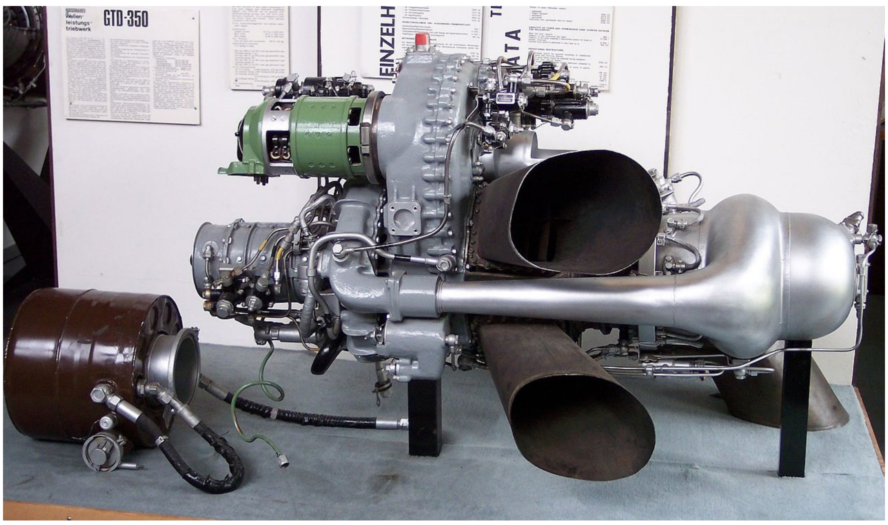

Fig. 3. The GTD-350 helicopter turboshaft engine

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Використання піролізного газу в якості пального для газотурбінних двигунів з метою їх використання в енергетиці

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Метою даної статі є показати можливості застосування піролізного газу в якості пального для ГТУ зі списаними ГТД, в т.ч. авіаційними — турбогвинтовими або турбовальними, а також наземного застосування та корабельних. Методи: стаття описує технології піролізації різноманітних речовин для отримання піролізного газу та подальше його застосування в якості пального для ДВЗ, розроблені з кінця XIX ст., що успішно застосовувались для автомобільних, судових та залізничних ДВЗ до середини XX ст., коли було відкрито величезні запаси нафти по всьому світові. Результати: дане дослідження доводить не тільки існування економічної вигоди застосування піролізної технології в наші дні, а також екологічної вигоди через причину можливості утилізації побутового та промислового сміття. Обговорення: запропоновані приклади успішного використання піролізної технології можуть бути гарною базою для подальшого дослідження переводу сучасних ДВЗ на пальне з піролізного газу.

Ключові слова: *піроліз, газотурбінні двигуни, газогенератори, піролізний газ, альтернативні палива, електроенергетика, подовження ресурсу.*

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Применение пиролизного газа в качестве горючего для газотурбинных двигателей для их применения в энергетике

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Целью данной статьи - показать возможности применения пиролизного газа в качестве топлива для ГТУ из списанных ГТД, в т.ч. авиационных — турбовинтовых или турбовальных, а также наземного применения и корабельных. Методы: статья описывает технологии пиролизации разнообразных веществ для получения пиролизного газа и дальнейшего его применения в качестве горючего для ДВС, разработанные с конца XIX в., которые успешно применялись в автомобильных, корабельных и железнодорожных ДВС до середины XX ст., когда были открыты большие залежи нефти по всему миру. Результаты: данное исследование доказывает не только существование экономической выгоды применения пиролизной технологии в наши дни, а также экологической выгоды по причине возможности утилизации бытового и промышленного мусора. Обсуждение: предложенные примеры успешного применения технологии пиролиза могут быть базой для дальнейших исследований перевода современныъ ДВС на топливо из пиролизного газа.

Ключевые слова: *пиролиз, газотурбинные двигатели, газогенераторы, пиролизный газ, альтернативные топлива, электроенергетика, продление ресурса.*

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