CREATING THERMOCHEMICAL REACTORS BASED NANOCATALYSTS FOR THE CONVERSION OF FUEL VAPOR SYSTEMS

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To ensure the functioning of active thermal protection systems and conversion of hydrocarbon fuel of gas-turbine unit, including nuclear and solar plants, internal-combustion and atmospheric jet engines requires the novel functional and structural materials of catalytic class and thermo-chemical reactors based on these.

The thermochemical reactors operating in the steam reforming of fuel and chemical regeneration of heat must have a high thermal conductivity, low hydraulic resistance, high mechanical strength, vibration strength, thermal strength, and high performance for the power block efficient operation.

Specified requirements are satisfied the catalytic nanomaterials based on the volume-porous active structures synthesized directly to the metal heat-absorbing surface, as well as the catalysts based on metal highly-porous cellular and disperse materials.

As shown by tests the nanocatalysts based on the metal ribbed and corrugated supports obtained by coating of stabilized aluminum oxides, activated by compounds of transition and rare-earth metals must have a coating thickness of not less than 100 microns and the efficiency of the steam conversion of fuel up to 70 - 85%.

Creation of nanostructure in the matrix ensures extensive increasing a number of mechanical and physicochemical properties.

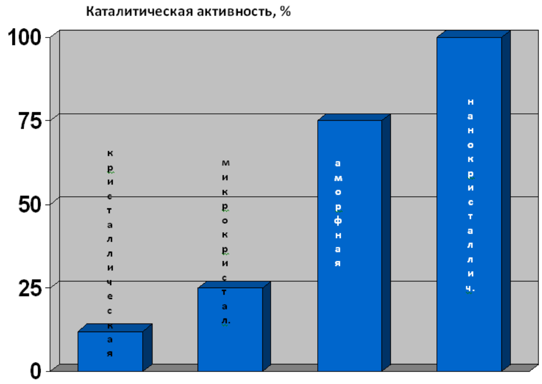

Fig.1. Benefits of nanomaterials

The efficiency of the catalytic thermochemical reactors is composed of at least three components:

- High catalytic activity of nanostructured volume-porous active structures synthesized directly on the metal heat-absorbing surface;
- Optimal design of the thermochemical reactor, which allows to minimize a heat loss, to reduce the flow resistance to the working gas, to increase by several times volume rate of the process, to ensure the reduction of the temperature of the reactor wall to significantly increase endurance of the reaction to produce highly efficient hydrogen fuel;
- Optimization of operational parameters of the propulsion system , the creation of high-precision dynamic feedback system between the parameters fuel conversion.

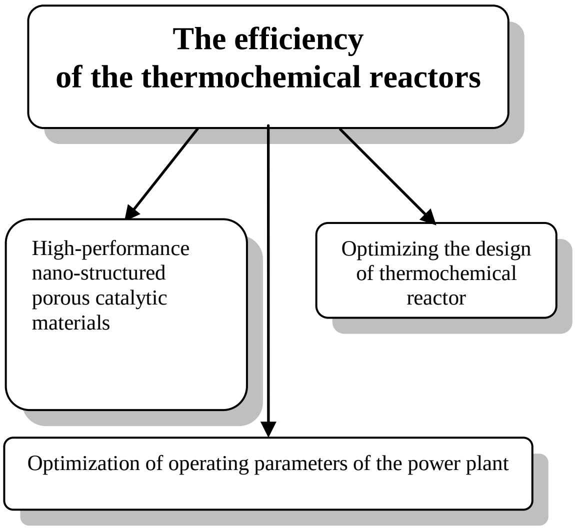

Fig. 2. Factors determining the effective operation of thermochemical reactors

The technology of fuel efficient catalysis using thermochemical reactors used in various industries that use hydrocarbon fuels.

Due to variety of possible models of the fuel conversion processes the researches were carried out taking into account the operational conditions of use of thermochemical reactors:

- Low temperature conversion, working temperature up to 600˚ C;

- High conversion, working temperature up to 1000˚ C.

Development of nano-structured porous catalytic coatings was conducted in two directions:

- Using of porous nano-catalytic support based on heat stabilized gamma - aluminum oxide system with the introduction of rare-earth and transition metals oxides. The primary method of applying an activator - "sol-gel" technology with a system of catalytic "start";

- Using of basic nano-catalyst aluminum-nickel system with cellulating and activating agents. The primary method of nanostructuring is «island» coating of amorphous and nanodispersed particles of nickel by method of evaporation condensation on macrostructured matrix.

One of the promising ways to obtain the volume-porous coating is a method of microplasma spraying, as it, in contrast to traditional gas-thermal spraying methods, is capable of applying coatings on thin-walled products without risk of overheating and warping, provide a high adhesive and cohesive strength of the coating with a developed surface and to preserve the original with no degradation of catalytically active structure of the deposited material in the coating.

It was established experimentally that microplasma spraying of traditional powdered materials such as powders of aluminum gamma-oxide, aluminum hydroxide and powder mixtures of aluminum and hydroxide aluminum occurs at high enthalpy plasma jet from 10 to 15 kJ/g. It does not allow obtaining coatings with high content of catalytically active γ-Al_2O_3 (more 70%) because γ- Al_2O_3 turns into high-temperature modification of α-Al_2O_3 through plasma jet thermal effect on sprayed material.

Therefore the principle of obtaining composite powders «Al/Al (OOH)»-system by granulation method was developed, the use of which has enabled the deposition at low values of the enthalpy of the plasma jet from 8 to 10 kJ/g and obtain coatings with γ-Al_2O_3 content more 70%.

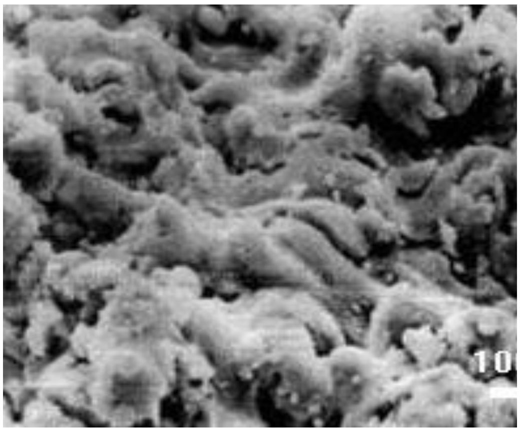

Fig. 3. The structure of the deposited layer of the nanocatalyst (porosity of up to 30 m^2/g)

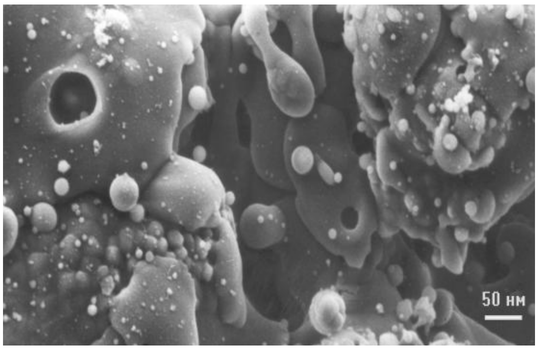

Fig.4. The structure of the deposited nano-catalysts layer after heat treatment (porosity of up to 50 m^2 / g)

The experimentally determined patterns influence the composition and structure of the initial composite powder materials of «Al/Al (OOH)» on the adhesion strength and porosity of the obtained volume- porous coatings. Found that with increasing aluminum content in the initial composite powder material of «Al/Al (OOH)» increased adhesive strength of sprayed coatings based on γ-Al_2O_3. It is shown that with increasing content of aluminum hydroxide in the initial composite powder of «Al/Al (OOH)» increases the content of γ-Al_2O_3.

Decisive importance in choosing the design of a catalytic reactor and the mechanical strength of the catalytic material on a metal carrier has the option of the metal base or primary carrier.

As the metal base can be selected by the following heat-resistant materials:

- ferritic steel, the iron - chromium - aluminum - for $t \leq 1000°$ C,
- austenitic steel, nickel-chromium system - for $t \leq 900°$ C,
- heat-resistant nickel alloy - for $t \leq 900°$ C,
- heat-resistant chromium-nickel alloy - for $t \leq 1200°$ C.

In accordance with the terms of the processes for 600-900° C based on the analysis makes high-temperature alloys , as a metal substrate is most advisable to use heat-resistant alloys X20H80, 07X18H10T with operating temperature up to 1000-1100° C, which are produced in the form of cold-rolled sheet and strip in thicknesses ranging from 0,05 mm to 1,0-1,5 mm. The alloys are welded by TIG welding and various methods of welding: seam and spot.

For further experimental work the following thermochemical reactors' designs was considered:

- Planar thermochemical reactor, consists of two parallel panels with wall thickness up to 1,0 – 1,5 mm, with catalytically active composition applied on its inner surface;
- Cylindrical thermochemical reactor (Fig. 5) consists of two coaxially arranged cylinders, with the catalytically active composition applied on the outer surface of the smaller diameter cylinder and on the internal surface of the greater diameter one.
- A combined version of the planar thermochemical reactor (Fig. 6) with selected the heat-resistant alloys of X20H80 and 07X18H10T grades and that can be used directly in the form of sheet or slotting grid. In this embodiment the space between the both catalytic panels is filled with a catalytic material applied on slotting, corrugated grid. Thus, in the realization of such thermochemical reactor configuration the macroporous structure as a secondary porous support of catalytically active centers is created.

Fig. 5. Cylindrical thermochemical reactor

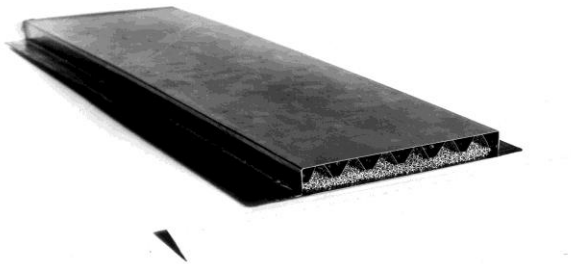

Fig.6. Combined version of the planar thermochemical reactor

The design based on a metal alloy and manufacturing technology TXP as the assemblage into one of the separate elements have been satisfied the following requirements:

- Welded seam should not be exceed 3 - 5mm;
- Welded seam must not contain fillets, weld defects and burns on the next catalytic surface;
- Welded seam should not be include unwanted elements of a catalyst system, since they can form unwanted intermediate compounds and deactivate the process of fuel decomposition.

In this regard the method of laser welding has proposed as the basic technology of thermochemical reactor. The modern software for technology process and laser robotic installation allows creating the desirable design. The spot welding technique may use in addition for fixation of catalytic material in reactor's workspace.

Different versions of the design and technological aspects of thermochemical reactors for the steam conversion of fuel using nanostructured catalysts on the base of the volume-porous active structures, synthesized directly to the metal heat-absorbing surface are considered.

The main advantage of the technologies is the possibility of obtaining high efficiency mechanically strength thermochemical reactors for use in a wide variety of fuel conversion. Catalytic materials and corrugated metal fin carriers, synthesized in the heat sink surface and thermochemical reactors based on these will be widely used in transportation energy, stationary gas turbines of power plants and gas compressor stations , the chemical energy technologies that are promising devices for converting solar energy and nuclear.

References

1. B.V.Farmakovsky et al. «Research and development of catalytic nanomaterials with amorphous and microcrystalline structure for steam reforming of hydrocarbons». - The 5th Int. Simp. «Thermochemical and plasma processes in aerodynamics». - St. Petersburg, 2006.