EXPERIENCE OF CREATING A NEW TYPE OF VORTEX GAS GENERATORS FROM SOLID ORGANICS

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Continued use of the coal, biomass or combustible solid wastes gas-generation at thermoelectric power stations (hereinafter – TPS) and boiler rooms is substantively constrained by the problem of treatment of combustible gas produced of tar and ash. Without this intensive treatment cleaning gas cannot be supplied into efficient internal combustion engines (hereinafter – ICE) and especially – into effective gas-turbine units (hereinafter – GTU) in different units of constant and even temporary supply of low electric power on the wholesale energy markets. This limitation we see, among others, in the existence of gas generation gases of acids HF or HCl, sulphur oxides, heavy metals, sometimes alkaline and other chemical elements that are not only ecologically dangerous, but perhaps may chemically and physically interact with the first stages of the GTU blades and ICE components. This will increase the accidents probability and decrease the readiness of installations to provide the declared electrical power, which is unacceptable in the operation on the electric power commercial markets.

Therefore, we believe that it is more prospective to organize gas-generation on the basis of cheap local fuels with low costs, wastes and biomass for generating electrical energy, and heat energy only by burning the gas of gas-generation in small units of local energy consumption. The original solid fuel should be cheap, and preferably – free of charge. Our experience has shown that the best fuel for small-scale gas-generation is that, which is a waste product, and for its removal and disposal the owners of the company are to pay considerable funds to other firms.

In these conditions it is possible to find the commercial expediency of obtaining one or two types of secondary energy and even only heat from generator gas. It is often possible even in the schemes of simple gas purification, and sometimes even without gas purification, and it would be necessary to refuse from GTU installation because of the high cost of their implementation and complicated operation, even, perhaps, from the ICE installation.

The decisive influence on the implementation of commercial gas generation may be exerted by an energy consumer, defining the parameters of the installation. Perhaps it will even be isolated from the network companies electricity consumption, but is not excluded, and parallel operation with them. In this case, we believe that it is perspective to plan installations for systems of distributed generation. Therefore, exact formulation of practical challenges of implementing the gasification process will determine the choice of its technology with a complex preparation of gas for combustion in boiler, or in ICE or GTU. Combustible gas in these probably small facilities of power generation, cogeneration, and in boiler rooms is better to be obtained from wastes, biomass or peat, including - in mixtures with coals.

For these cases, known for us, we have already developed and implemented vortex gas generators, as we believe, - of a new type. We have put two groups of works of the authors in the basis of a new gas generation reactors. One of us from the end of the twentieth century has being studied gas-generation of biomass, peat, waste and coals in conventional types reactors, and in 2004 has developed a single-chamber vortex gas-generator from sawdust. When creating a commercial unit there was the need of solving the problem of vortex control. For these purposes for the first time there have been used techniques, proposed and studied previously by another author in the study of burners, cyclones and cameras models in 70-80-s of the twentieth century. In this study, the formation of the intensively swirling vortex in volutes and cyclones has been studied in detail, and the view of the development of vortex in chambers and in пристыкованных to them cylinders has been significantly expanded, and the new mechanisms of influence on the structure of vortex in similar devices have also been proposed and investigated.

After 2004, part of the works has been restored, they were developed and supplemented. We have developed and studied on the models on a dusty air dozens of variations of components of gas generators, vortex furnaces and burners, having from two to six consecutive vortex chambers for the passage of developing, controlled vortex. About 20 variants of device models have been tested by us on the fire. In these original devices, we have substantially implemented the many advantages of vortex technologies of generation and combustion. It is needed to emphasize the increase in the time of fuels and gas stay in the reactor for 1-2 orders with the division of the process into stages, and most importantly – with the ability to manipulate the environment and the temperature of the process at all stages. This is necessary for operation on unstable, polydisperse raw materials, including even for increase of the carbon elimination or partial capture of CO_2 by oxides of calcium ashes, and for the suppression of the content of harmful substances, especially carcinogens, CO and even NO_x. There has appeared the possibility of separation of the solid phase by groups of fractions in the reactor.

In our works we have managed to solve this problem partially. For this we have taken as the main conception, the idea based on the distribution analysis of particles in its volume of density distributions of moment of rotation flows and axial impulse in it, associated with turbulent structure. This provided us the possibility to make basic solutions for two-phase vortexes with fuel burning. For this we use only highly twisted flows (vortexes), in which the intensity of twist is always above the level necessary to save the counter-flow (paraxial reverse current) on the axis of rotation. In this case, it is possible to create the conditions, where in different zones of the burning vortex strengthening or weakening of mixing is taken place, and localization of these zones can be controlled in the vortex. Our experience has confirmed that these processes are caused by changes in the intensity and direction of turbulent transfer in a vortex, and in a complicated way are connected with the structure of the vortex, for the description of which there is still no universal model, especially in the non-isothermal vortex and in a two-phase vortex with an active axial flow. Therefore, for most of the vortex devices exists an unsolvable problem of creation of effective technological influence on the processes in them. The satisfactory solution of this problem is not yet available for many developers of gas generators and other related commercial purposes vortex devices.

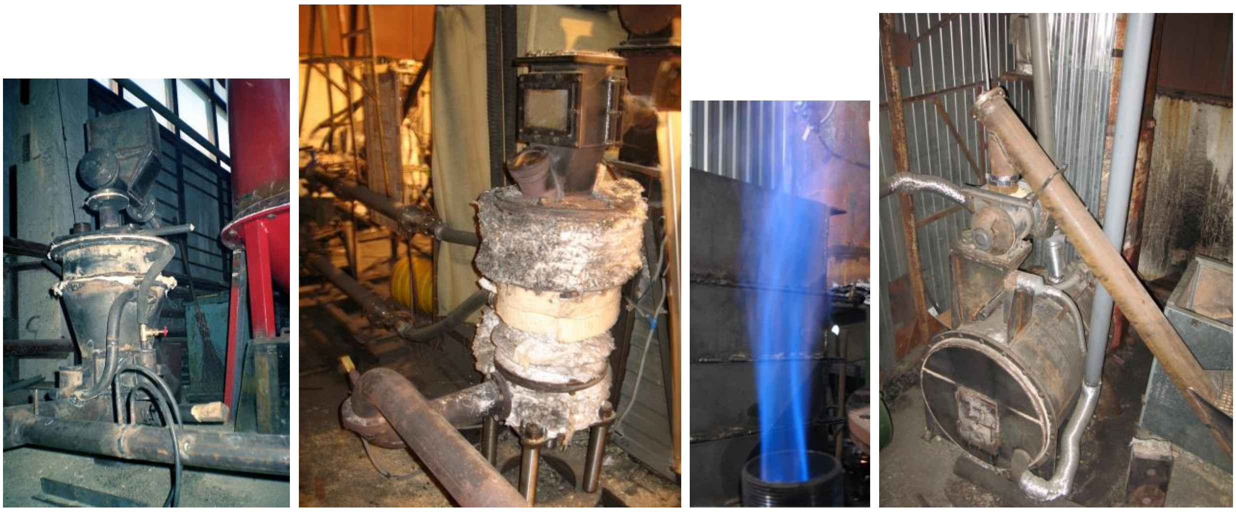
In respect of vertical vortexes we have solved the problem of introduction with the solid phase of the chamber swirlers, located in the bottom part of some devices at speeds of only 4-5 m/s, and have reduced the asymmetry of the vortex at the output of the cameras and have eliminated the fall-through of sediment down into the swirl at the same speeds. There has also been received the focused concentration and holding on the outer wall of cameras of large particles of sediment, as well as the concentration and retention in a suspension of fine fractions in a separate zone of the reactor. For this purpose we have created the original vortex aerodynamic trap for particles of 3-5 microns and less. For the vortex with a horizontal axis we have solved the problem of sufficiently stable retention of sediments in the zone of primary vortex spin with more equal filling of the wall zone with the suspension.

Strong deposition of sediment at the bottom of the camera, interfering the process, has been eliminated even at speeds of 5 - 7 m/s. Moreover, the measures of wall movement of sediment near the vortex chamber in two directions have been developed, we have even managed to distinguish some lateral vortex layers in it with the decrease of its asymmetry at the output. The effects of the intensification and slowing of heat and mass exchange in some zones of vortex and in the channel, located behind it. The time of suspension stay in vortex has been increased, first of all, to move along the vortex of vortex chambers with or without supply of solid suspension or air. When creating commercial vehicles we have selectively implemented some of these above mentioned results of the models research, sometimes after being subjected to more subtle effects and constructive decisions on other objects.

The first device of a vertical type gasification for sawdust has been created, manufactured and tested in 2004 (Fig. 1a). Further, its scheme has investigated and developed by us in varying quantities of peat, coal, and its mixtures with biomass on models with capacity of up to 0.4 - 0.5 MW for the heat of combustion gas (Fig. 1b).

In 2007 we have created a simple purification system of part of gas for submission to the internal combustion engine (Figure 1c), and for burning of another part of gas in a furnace there has been proposed a new vortex burner. The prototype of 50-60 kW capacity, has been tested and showed steady burning and many possibilities of burning torch control. On the basis of new reactors and burners we have proposed and tested a simple powdered-coal burner with capacity of up to 100 kW, passing next to the combustion chamber of heat capacity of 0.5 - 0.6 MW (Figure 1d). In fact this object can be considered as a fundamentally new vortex burner with partial or complete managed internal gasification of coal dust (up to 1 mm). These devices showed stable torch burning of partially gasified dust in the mixture with the generator gas in cold atmosphere, allowing these devices to be offered for lighting of furnaces on the plant's own coal dust.

In order to increase the capacity and manageability of new gas generators, as well as to reduce the content of ash and tar in gas there has been created a series of units with horizontal vortex, tested on models of up to 0.6 MW. One of them is also shown on (Fig. 1e). It has been put by us in the basis of more powerful machines, which are designed now for commercial use.



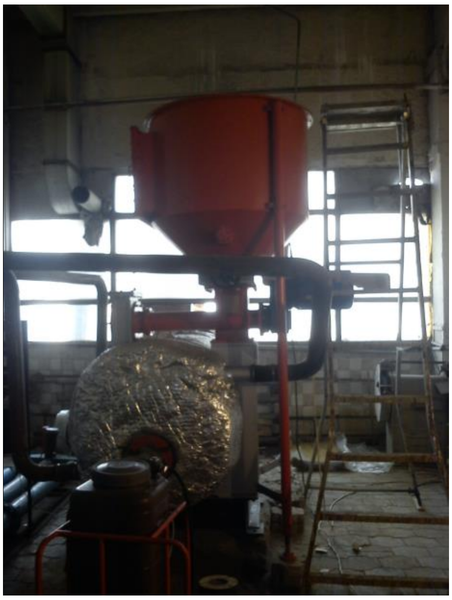
a) *b)* *c)* *d)*

Fig. 1. Some of the new type experimental vortex gas generators:
a) on sawdust (2004); b) – on sawdust, peat, coal, bark (2005 - 2006);
c) purified gas generator for supplying to ICE (2006 - 2007);
d) coal, shale and different mixtures gas generator (2010 - 1011).

The first three-chamber commercial unit, with capacity of 2.5 MW for the heat of the obtained gas, has been developed and implemented in 2011 (Fig. 1e) for oats husk gasification (Figure 2a). Continued testing, and starting from 2012, constant commercial operation with the simplest equipment for purification and preparation of gas for combustion in the boiler, has provided the material for commercial reactors of sawdust gasification (Fig. 2b), peat, other husk and biomass. Finalization of the appliance (Fig. 1e), it's successful, sufficiently long commercial operation demonstrated beneficial effects, that significantly increase the investment attractiveness of the gas-generator of this structure and potential productiveness for the development of its technological scheme.

Firstly, opening the unit after two years of operation, including all its completion, testing of various modes, dozens of connections and disconnections, have revealed complete lack of soot and even black plaque on the walls of the third output reactor chamber, named the "conditioning camera" by us. When gas temperature at its output reaches 750-850 °C, this means that heavy resins, having higher boiling temperature, has been exposed to thermal decomposition (conversion) in the chamber. It is possible that part of lighter resins has also been exposed to pyrolysis, and heat of gas combustion is above the estimated one, approximately equal to 1200 kcal/Nm^3. The data, received on that device and fuel, when the heat of combustion of gas was one and a half times higher than the heat of combustion of gas, obtained from the same fuel in traditional layer gas generators of the "Lurgi" scheme, demonstrates the same.

e)



f)

Fig. 2. Commercial vortex gas generators of a new type:
e) oats husk (2011 - 2012); f) on sawdust (2012)

Husk reactor forcing and pyrolysis in the first chamber increased its capacity in 2.5 - 3 times, and with acceleration of the autostabilization mode when at the oscillations of the biomass supply and quality, the device automatically restored the air balance, though, and for some, but generally admissible fluctuations of the natural gas flow and quality at its furnace combustion. We also consider to be perspective creation on the basis of the schemes of the vortex formation and control schemes in multi-chamber devices, having been tested by us, and even in their working commercial samples of entirely new class of vortex furnaces. The same new original schemes of two or three chamber vortex units or furnaces, based on them, can be recommended for realization of combustion schemes of "Oxi - Coal Combustion" ("Oxi - Fuel Combustion") type in CCS technologies for "cutting off" CO_2. This is important in arrangement of implementation of the country-specific fossil fuels combustion schemes for the purpose of "cutting-off" and further disposal of CO_2 in the process of solving the climate protection problem, regardless of the attitude of some authoritative experts in respect of it. It is advisable to use our equipment for the production of synthetic liquid fuels. For example, using one of our tested devices with capacity of up to 0,4 MW at the experimental processing of the bleaching clay in production of vegetable oils, we have managed to reduce the temperature of the process to the level of 300ºC. In the short run, we have even managed to get the stable gas-generation of organic bleaching clay at a temperature of just 200 OC. The obtained generator gas has been burning in a furnace as straw oil vapour.