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HYDROGEN PEROXIDE INDUCED ACTIVATION OF METHANE COMBUSTION IN GAS TURBINE ENGINE

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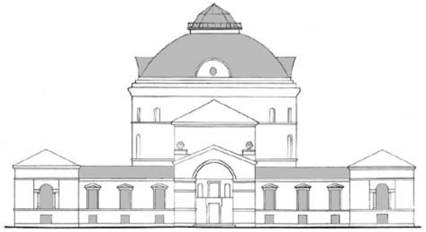

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Wet Compression Cycles:

HAT (Humid Air Turbine),

TOPHAT,

CHAT (Cascaded Humidified Advanced Turbine)

SwirlFlash - Stork Thermeq.

Substantial surplus of power output is achieved owing to quasi-isothermal air compression within air compressor of GTE with such cycles. NOx emissions in such cycles are reduced.

The main problem

of those wet cycles is to obtain small sprayed water droplets injected into GTE, usually <u>smaller than 3 microns in diameter</u> in order to guarantee evaporation of droplets inside CC and prevent negative slow down of a CO oxidation and incomplete combustion due to presence cold water droplets.

The main problem

Many techniques had been elaborated in this art in order to get an uniform and fine atomization of sprayed water. But all of them have potential drawbacks of incomplete combustion and growth of CO emission

Our Improvements of Wet Compression Cycle

We propose to overcome the above drawbacks by means of addition of hydrogen peroxide to the injected pulverazed water.

Our calculations have shown, that addition of hydrogen peroxide results to more effective combustion, accompanied by shortening of induction period and increasing of maximum velocity of temperature growth.

The aims of the present work

To perform computer simulations of methane combustion in GTE with wet cycles in presence of droplets, containing aqueous solutions of hydrogen peroxide.

To calculate the influence of evaporating droplets upon the composition and temperature of surrounding gas.

To stimulate the process of concentration changing during vaporization of the droplets of aqueous solutions of hydrogen peroxide.

Models used for investigations

1) **Computer code “NEIKIN” (*Basevich V.Ya., Kogarko S.M., Neighauz M.G., 1976*) simulating premixed combustion of air-fuel mixtures with water and hydrogen peroxide additives was used to investigate the dynamics and mechanism of high-temperature chemical processes in GTE combustors.**
2) “Reactor" model of the combustion chamber based on commercial software package Chemical Workbench version 2 Standard was executed for trial calculations of influence "injection" of water containing small addition of hydrogen peroxide, to ignite the fuel mixture
3) **Dynamic model of droplets vaporization based on MathCad 13 (Rkadapt) was used to study the process of hydrogen peroxide saturation within remaining droplets.**

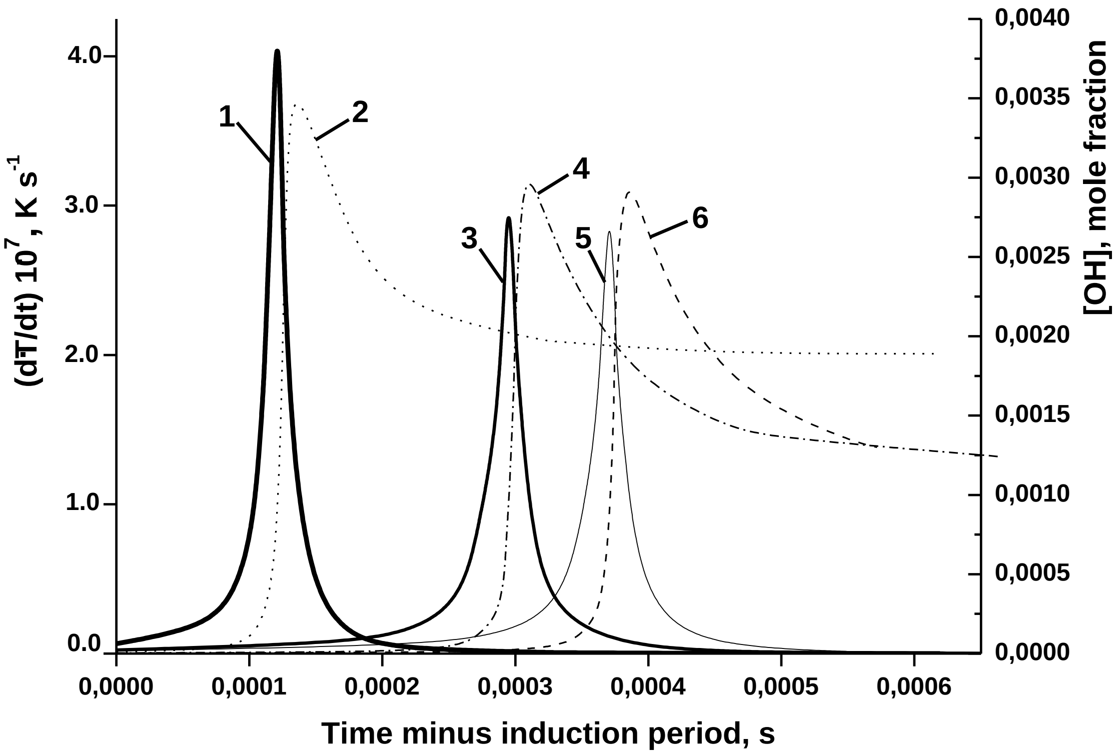
Results of computer stimulation

Computer simulation revealed, that hydrogen peroxide addition substantially lowers the time (induction period) needed for heating gas mixture from initial temperature (680K) to 1000K, and also lowers the time needed for heating gas mixture from 1000K to 1650K where maximum velocity of temperature growth (dT/dt) was reached.

Activation of methane combustion with addition of hydrogen peroxide.

Name of parameter	H_2O_2 in injected water, wt %		
	0	1	10
Relative induction period (heating from 680K till 1000K)	1.0	0.44	0.11
Time needed for self heating from 1000K till 1650K, ms	0,370	0,300	0,125
Relative time need for heating from 1000K till 1650K	1.0	0.80	0.34

Activation of methane combustion with addition of hydrogen peroxide



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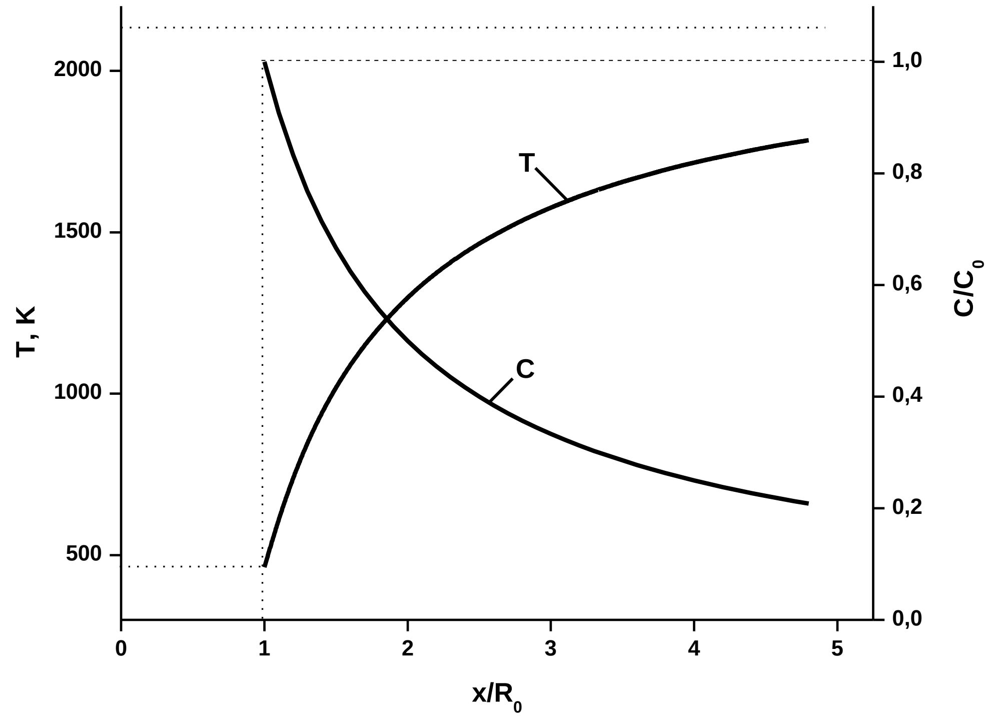
Saturation of hydrogen peroxide solution promotes to growth of its activation ability

Time, *ms*	Water, *wt* %			Hydrogen peroxide, *wt* %		
	5 μm	10 μm	15 μm	5 μm	10 μm	15 μm
0.00	99.00	99.00	99.00	1.00	1.00	1.00
0.05	98.778	98.957	98.987	1.222	1.043	1.018
0.10	98.494	98.901	98.963	1.506	1.099	1.037
0.15	98.147	98.842	98.938	1.853	1.158	1.062
0.20	97.724	98.78	98.914	2.276	1.22	1.086
0.25	97.207	98.715	98.888	2.793	1.285	1.112
0.30	96.579	98.646	98.862	3.421	1.354	1.138

The estimations of the dynamics of concentrations and temperature changing during the evaporation of droplets

The influence of cold water droplets on the composition and temperature of surrounding hot gas substantially weakens with increasing of distance from the surface of droplets



Oxidation of CO to CO_2 is a chain process:

$$OH + CO \rightarrow CO_2 + H,$$
$$H + H_2O \rightarrow H_2 + OH$$

In order to complete CO oxidation, it is necessary to increase OH concentration and water content. Increasing of OH concentration is a motive for reduction of CO concentration. For increasing OH concentration in local low-temperature zone near the droplets, admixing of hydrogen peroxide with pulverized water is a certain effective method, because of thermal decomposition of H_2O_2 producing in situ two hydroxyl radicals: $H_2O_2 \rightarrow OH^{\cdot} + OH^{\cdot}$.

Some essential remarks

Admixture of H_2O_2 to pulverized water has additional advantage: H_2O_2 gives an oxygen as a result of its thermal decomposition:

$$2H_2O_2 \rightarrow 2H_2O + O_2.$$

These oxygen molecules along with an air take part in fuel oxidation therefore the quantity of the compressed air can be accordingly decreased giving an economy of power expenditure for compression resulting to the surplus of power efficiency of above cycle.

Some essential remarks

According to the equation: $2H_2O_2 \rightarrow 2H_2O + O_2$ as a result of thermal decomposition two molecules of $2H_2O_2$ form three gaseous molecules i.e. there is one additional molecule or additional volume of compressed gas, which will be used to drive gas turbine giving additional power output due to the intrinsic energy of H_2O_2 molecules.

Moreover, said thermal decomposition of hydrogen peroxide droplets within combustion chamber promotes atomizing of remaining droplets.

Concluding Remarks

The injection of hydrogen peroxide into CC results to more effective combustion, accompanied by shortening of induction period and increasing of maximum velocity of temperature growth. Due to predominant evaporation of water from droplets at high temperature saturation of initial hydrogen peroxide solution occurs inside residual droplets: they gain sufficient concentration of hydrogen peroxide which can undergo thermal decomposition within CC, promoting atomizing of remaining droplets. Such thermal decomposition of hydrogen peroxide droplets serves as a local sources of hydroxyl radicals and oxygen promoting to acceleration and activation of methane combustion at cold zones near the surfaces of the droplets. This give rise to more effective combustion in gas turbine engines leading to higher power efficiency of GTE and essential economy of fuel besides of reduction of CO and NO_x emission.

Acknowledgments

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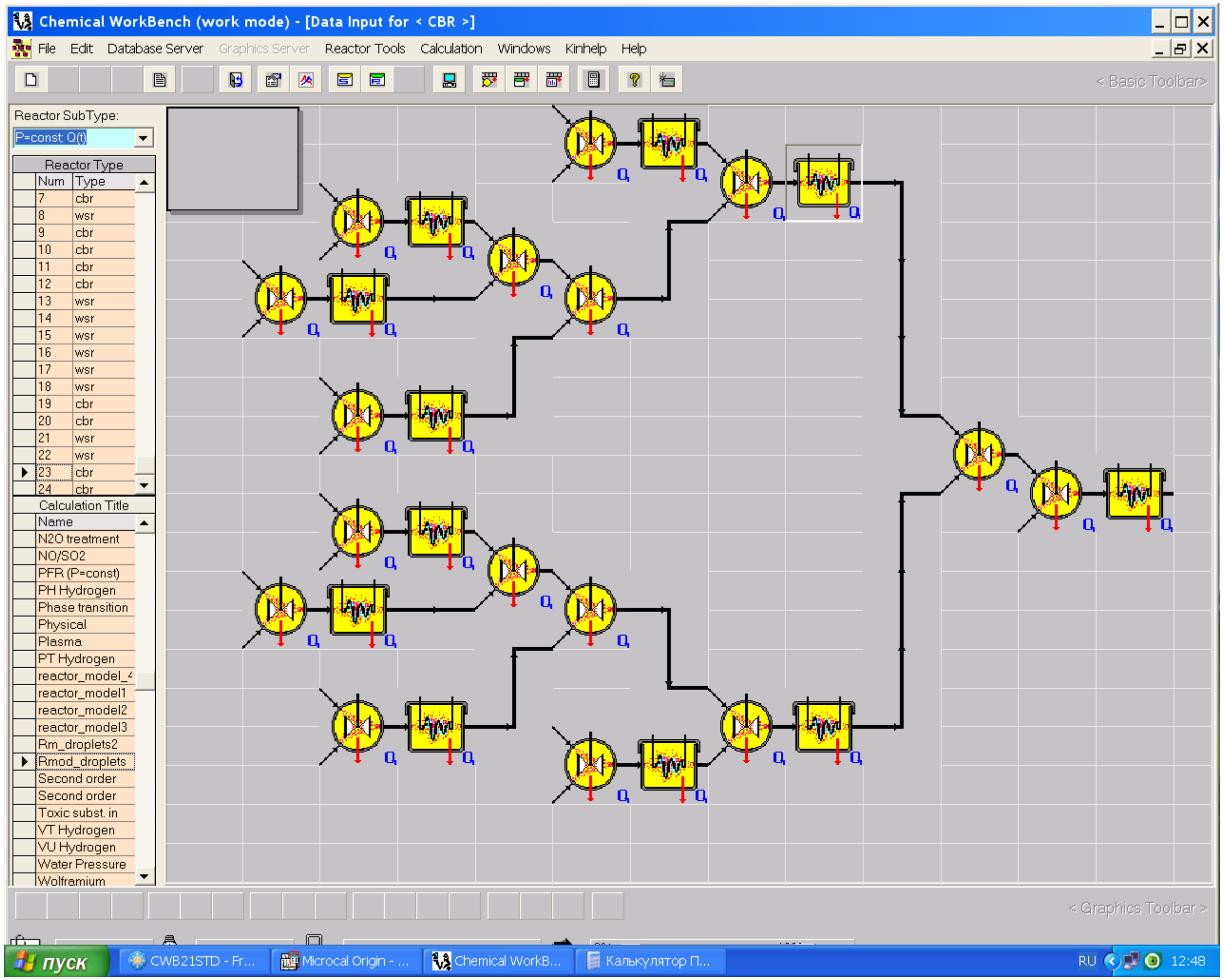
Thanks for your attention!

“Reactor" model of the combustion chamber based on commercial software package Chemical Workbench version 2 Standard



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