UDC 621.43.004.18

# INCREASE EFFICIENCY cogeneration plants based on internal combustion engines BY humidification

***IV Feofilov Engineer***

*The analysis of different types of cogeneration units from the point of view, the fuel economy is a comparison of existing means of adding water to the fuel-air mixture in ICE and show the possibility of increasing the efficiency of cogeneration plants based on internal combustion engines by moistening duttovoho air.*

***CHP, adding water to the fuel condensation heat of heat.***

**Problem.** The combined power generation using cogeneration plants (CHP) was recognized as one of the most promising technologies that enables efficient power supply along with solving problems saving fuel and improve the environment. Among the many types of cogeneration plants would be interesting to identify the type of cogeneration plants that yield the greatest fuel savings, and consider the possibility of increasing their efficiency.

**Analysis of recent research.** High energy performance CHP due to utilization of associated heat generated by direct electricity generation. The main indicator of efficiency CHP is total coefficient of performance (COP), which reflects fuel efficiency, it is called the coefficient of fuel [1]. The overall efficiency is the ratio of plant produced electricity and heat energy to fuel consumed. In terms of overall power efficiency CHP can be written as:

$$\eta = \frac{N_e + Q_m}{Q_{ког}} = \eta_e + \eta_m \ ,$$

where *Ne* - Useful electrical power installation, which is the electrical power to the generator terminals less electrical power used for personal needs; *Qt* - Useful heat output transmitted to the user; *Qkoh* - The heat released during combustion in a cogeneration unit per unit time; *ηe* and *ηt* - Electric and thermal efficiency CHP respectively.



Among power generating plants that burn fuel, CHP have the greatest efficiency, which is about 90-92%, calculated on the lower calorific value. Although the overall efficiency of different types of CHP approximately the same ratio of electric and thermal efficiency they are different. The overall efficiency of CHP does not show that the ratio of heat and power cogeneration in the most profitable and thus does not show what type of CHP provides a highest fuel economy in its use.

**The purpose of research.** Select the type of cogeneration plants that yield the greatest fuel savings, and consider the possibility of increasing their efficiency.

**Results.** Information on the most fuel savings can be obtained by analyzing the ratio of fuel economy ε for cogeneration units with different ratios of heat and electricity at the same values of total efficiency. Coefficient fuel economy ε describes the reduction of fuel consumption for heat and electricity cogeneration with respect to fuel consumption at a separate formulation of the same energy:

$$\varepsilon = \frac{Q_{окр} - Q_{ког}}{Q_{окр}} ,$$

where *Qkoh* and *Qokr* - Thermal energy spent fuel at thermal and electric energy cogeneration scheme and in particular the development of the same energy, respectively.

Specific fuel consumption (in units of heat) for the same values of electric and thermal power in particular the development of these energies are:

$$Q^e_{окр} = \frac{N_e}{\eta_e^{окр}} = \frac{\eta_e \cdot Q_{ког}}{\eta_e^{окр}} ; Q^m_{окр} = \frac{N_m}{\eta_m^{окр}} = \frac{\eta_m \cdot Q_{ког}}{\eta_m^{окр}} .$$

The total cost of fuel at a separate formulation of energy equal to:

$$Q_{окр} = Q^e_{окр} + Q^m_{окр} = \left( \frac{\eta_e}{\eta_e^{окр}} + \frac{\eta_m}{\eta_m^{окр}} \right) \cdot Q_{ког} .$$

Then the equation for the ratio of fuel economy takes the form:

$$\varepsilon = \frac{\left( \frac{\eta_e}{\eta_e^{окр}} + \frac{\eta_m}{\eta_m^{окр}} \right) - 1}{\left( \frac{\eta_e}{\eta_e^{окр}} + \frac{\eta_m}{\eta_m^{окр}} \right)} .$$

Based on the known data on the total efficiency of CHP and value generated in CHP heat and electricity can be calculated coefficient of fuel economy for different types of CHP.

We consider two limiting cases. The first limiting case where the ratio produced in CHP heat and electricity most (about 10), typical add-energy steam boilers and power generating equipment with gas turbine drive. The second limit is the case where the ratio of heat and electricity - the minimum (about 1). KSU corresponding to this case, includes in its membership, usually an internal combustion engine and waste heat boiler. In this setup, getting the maximum electric power. The combustion of additional fuel in active recovery boilers are intermediate between indicators considered marginal. If we take the total efficiency of CHP in the two limiting cases of the same (for example: $\eta$= 0.9), and the efficiency of separate production of heat and electric energy in equal $\eta eokr$= 0.32 and $\eta tokr$= 0.8, respectively, and use proportional method of allocating costs, by simple mathematical calculations, we find that in the first case, the limiting factor is fuel economy of about 0.3, and the second - more than 0.54. Thus, for the same values of total efficiency most important fuel economy and provides a cogeneration system, in which the ratio of heat and electricity least. That is, the greatest fuel savings can be achieved in CHP based on the internal combustion engine and therefore will continue to consider it a type of CHP.

In CHP useful products are manufactured electrical and thermal energy. Fig. 1 shows the possibility of improving the efficiency of the CHP. You need to increase the electrical and / or thermal power cogeneration system. As shown above, increasing the total efficiency of CHP should be, to primarily due to the increase of the electric component that allows you to get the most value fuel economy. Despite the fact that the value of electrical power for the type of fuel and power generating equipment of this size is the size of the factory ICE ways to improve $\eta e$ without change in the design of the engine there. First of all, - intensification of the processes occurring in the combustion chamber of the engine. And there may be several ways. One of them is - adding water during combustion. Historically, that experiments on the influence of added water on the performance of the engine was carried out for mobile vehicles. The results of these experiments can be fully used to analyze the possibilities to increase the efficiency of the cogeneration system based on ICE.

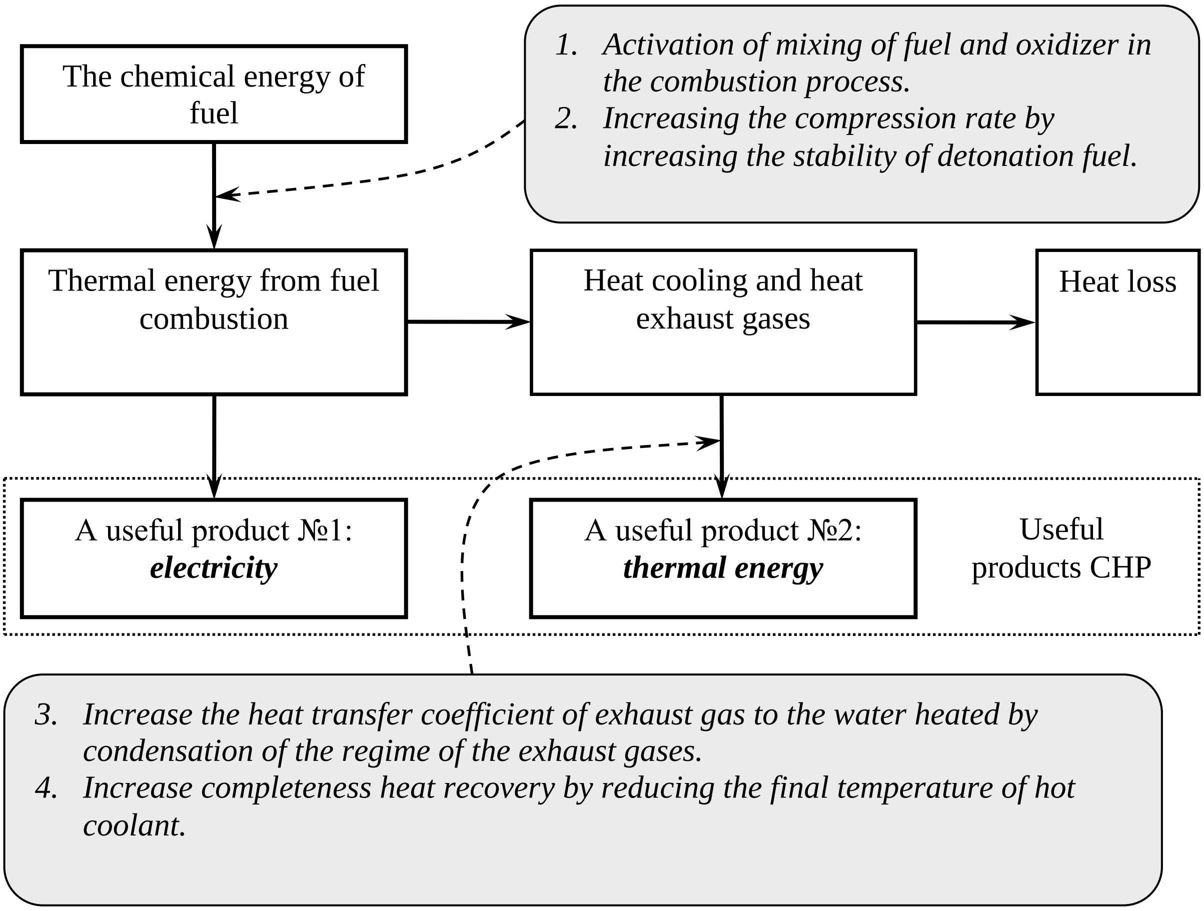


Fig. 1. Opportunities efficiency CHP.

The presence of water in the fuel-air mixture leads to its active mixing in the ignition and combustion of the mixture. As a result, increasing the contact area of fuel and oxidant and thus increases the heat released during combustion of the fuel unit. The growth of electric power in addition to 20% of water is about 10-15% [2]. We know that burning fuel with water leads to a reduction of Thermal Stress engine, improving the reliability of its work and increase the stability of the detonation of fuel, thus increasing the compression ratio and get even larger electric power. At a constant degree of compression allows adding water fuel with lower octane, and therefore cheaper. Data on detonation resistance of gasoline with different amounts of added water is given in Table [3]. Also, adding water to the fuel improves environmental performance power plant, reduced concentrations of nitrogen oxides and carbon formation. Experiments for pure isooctane and isooctane with 10% water show that such water content in the mix amount of CO in the exhaust gases of the engine falls to 6% NOh - 8% [4].

***Value octane gasoline for motor method.***

| Fuel | Number of added water | | | |
|---|---|---|---|---|
| | 0% | 5% | 10% | 20% |

| | | | | |
|---|---|---|---|---|
| Gasoline A-66 | 66 | 66.5 | 67.5 | 72 |
| Gasoline A-72 | 72 | 72.5 | 74 | 76 |
| Gasoline A-76 | 76 | 77 | 78 | 81 |
| Petrol AI-93 | 85 | 85.5 | 86 | 88 |

Also, adding water to the fuel improves environmental performance power plant, reduced concentrations of nitrogen oxides and carbon formation. Experiments for pure isooctane and isooctane with 10% water show that such water content in the mix amount of CO in the exhaust gases of the engine falls to 6% NOh - 8% [4].

Significant increase in octane number fuel reduction is explained by some authors temperature combustion of fuel-air mixture by evaporation of water added. Other authors attribute the Anti-knock properties of water not only to the lower temperature of the process, but also with the direct participation of water in the combustion process. The water in certain concentrations inhibits the development of chain reactions peredpolum'yanoho oxidation of hydrocarbons. Between peroxide radicals and hydroxyl group formed hydrogen bonding of water. Naturally, with the active radicals is reduced, and this in turn increases the stability of detonation fuel mixtures.

Adding water to the fuel injection is carried out normally or water in the fuel-air mixture before the burning of [5, 6], or by using a water-fuel emulsions [7, 8], which is prepared in advance. In terms of performance engines with injection water are not entirely stable. This is due to the uneven distribution of water in the cylinders of the engine. In addition, the water drops more than 5 microns, which fall into the engine cylinders may not have time to evaporate during combustion and then bombing is working surfaces of the cylinder and the piston, leading eventually to their physical deterioration. Use water-fuel emulsions allows to circumvent these difficulties. But there are others. To create metastable water-fuel emulsions of insoluble in each other liquids used third substances - emulsifiers that even with short term they use cause fouling in the combustion chamber and engine outages. In addition, emulsifiers and their decay products should be non-toxic, they have lower fuel detonation resistance. These additional requirements complicate the already difficult task of creating a stable water-fuel emulsions. Therefore, attempts to prepare emulsions directly by car, developed onboard dispersing devices to using hidrorozpylyuvachiv or ultrasonic generators obtain a dispersion medium droplets smaller than 5 microns. However, in these cases, the stability of emulsions must enter emulsifiers, albeit in smaller quantities. Considering the advantages and disadvantages of adding water to the fuel, and it should be noted that in both cases applied distillate, which is due to the receipt of additional significant energy consumption and the availability of appropriate equipment. Therefore, replacement of the fuel with water makes the corresponding fuel economy as to produce distilled water is also required to spend a certain amount of fuel. If you use nedystylovanu water, then the cost of its recommended to add to the fuel dissolved salts must necessarily lead to the formation of carbon in the combustion chamber and serious disturbances in the engine after 100-200 hours. After the burning of 10 liters fuel engine is brought to 2 liters of water, and with it, 200 mg of various salts. In addition, for the preparation of water-fuel emulsions as well as to obtain the required pressure in the injection of water also have to spend extra energy. So talking about significant fuel savings in both cases, however.

Different versions of adding water to the fuel-air mixture developed for engines located on a mobile vehicle, which necessitates the location of additional devices on it, which in turn leads to a decrease in net volume transport and increasing fuel consumption. These disadvantages can be eliminated if the addition of water to perform for engines that are permanently located KSU basis. In this case, no restrictions on the location of the necessary devices and no fuel consumption associated with their movement with the vehicle. Most of the other disadvantages of the use of water, while maintaining its positive effects on the combustion process can be eliminated if the use of water in the form of water vapor in the composition of moist air duttovoho [9, 10]. In this case, the cylinder will not get water particles greater than 5 microns, the distribution of water in the fuel mixture more uniform, which provides stable and reliable operation of the engine. Also, no need for emulsifiers and, accordingly, no deposits in the engine associated with it.

Hydration is in contact heat exchange apparatus by bubbling through a layer of water heated air that is sucked pistons in the cylinders of the engine. It's enough to heat the air in contact duttove heat exchanger at 10-15 ° C. For example, if the heat exchanger inlet air temperature is 20 ° C and relative humidity of 60%, and the output - 30 ° C and 90% (respectively), given the fact that the combustion of 1 kg of gasoline to about 14.7 kg air, adding water to get fuel in the amount of 20%. Thus the overall cost of heat for humidification not exceed 2% of the heat of combustion. Additional hydrodynamic resistance is less than 2 kPa. To heat the water to moisten the air duttove used heat engine cooling system. Moreover, to moisten the air duttovoho water can be used almost any degree of contamination, that eliminates the need for expensive distillate. In addition, the use of moist air does not lead to salt deposits in the cylinders of the engine, which positively affects its trouble-free operation.

Hydration is important for air duttovoho CHP also by increasing the humidity of exhaust gases. This allows you to get more dew point temperature at the disposal of flue gas engine and realize for heat recovery more efficient condensing heat exchangers. The energy balance CHP based DIC, running on gasoline, when moist air duttovoho without it shown in Fig. 2.

These energy balance transferred to the higher calorific value of the fuel for gasoline is Qvr = 47.3 MJ / kg. The overall efficiency of CHP without wetting duttovoho air to lower combustion temperature is: η = 0,9 (lower combustion gasoline: Qnr = 43 MJ / kg).

**Conclusions**

1. Of all the means of adding water to the fuel-air mixture for permanently situated CHP duttovoho humidifying air is the most effective.
2. Hydration duttovoho air, increasing the degree of compression and further condensing heat recovery of exhaust gases can increase the electric and thermal efficiency, and gain overall CHP to 0.98 at a higher calorific value fuel.

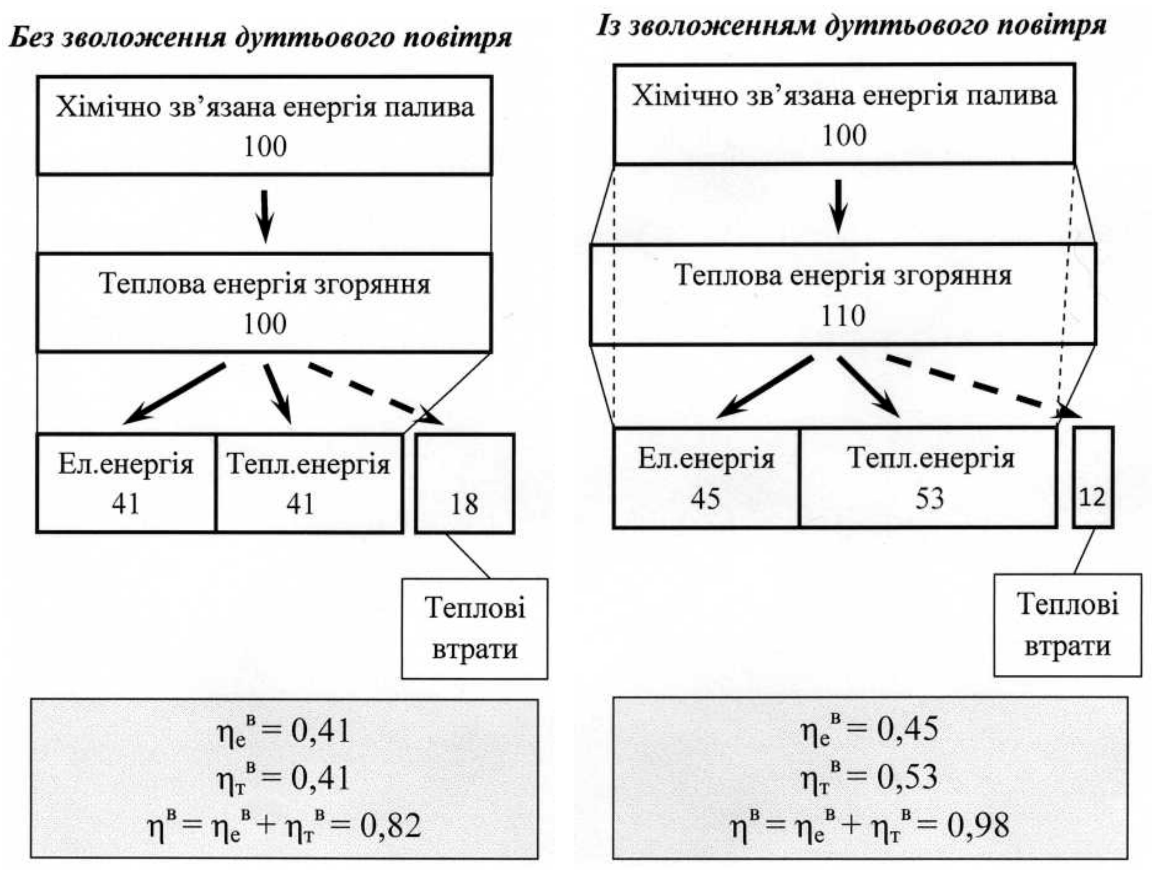


Fig. 2. Scheme CHP energy balance based ICE with moisture without wetting duttovoho air (at a higher calorific value of the fuel).

## References

1. *Klimenko VN* Kogeneratsionnye system with teplovыmy engine: cases. posobye: [3 hours.] Part 1: General question koheneratsyonnыh technology / *VN Klimenko, AI Mazur, PP Sabashuk.* - K .: IPTS Alcon NAS of Ukraine, 2008. - 560 p.
2. *Smal FV* Perspektyvnыe fuel for cars / *FW Smal, E. Arsenov*. - M .: Transport, 1979. - 151 p.
3. *Guyva SV* As water alternatyvnoe fuel / *SV Guyva* // Proceedings of the Tauride Agrotechnological State University. - Melitopol: Tavricheskiy State Agrotechnology University, 2009. - Vol. 9, v. 5. - P. 176-182.
4. *Efremov PK* C Question of Power Advanced thermal engines with water / *PK Efremov* // Proceedings Vsesoyuэnoy scientific conference "protection of air spaces basin pollution from toxic vыbrosamy transportation funds." - Kharkiv: In-Problems mashinostroeniya, 1977. - Part 1. - P. 221.
5. *Kolodin A.M.* Results tests of diesel 6CHN 16/22, oborudovannoho systemoy ysparytelnoho nadduvochnoho cooling air / *A.M. Kolodin* // Proceedings Novosibirsk Institute for ynzhenerov waterway. - Novosibirsk: NYYVT, 1981. - Vol. 158. - P. 76-87.
6. *Kapustin, VV* Ysparytelnoe nadduvochnoho cooling air / *VV Kapustin, A.M. Kolodin, H.H. Sorokin* // Rechnoy transport, 1978. - № 5. - P. 35.
7. *AN Lebedev* Vodotoplyvnыe эmulsyy in sudovыh Diesel / *AN Lebedev, VA Somov, VD Sysyn*. - L .: Sudostroenye, 1988. - 108 p.
8. *Lerman EY* Vыsokokontsentryrovannыe toplyvnыe эmulsyy - EFFECTIVE Improvement funds ecologically indicators lёhkyh bыstrohodnыh Diesel / *EY Lerman, O.A. Gladkov* // Dvyhatelestroenye. - 1986. - № 10. - C. 14-17.
9. AS 1306220 USSR, MKY3 F 02 B 43/00. Method of work vnutrenneho shorannya engine and combustion engine vnutrenneho / *AA Dolynskyy, AI Gurov, AN Podhornыy, AI Mishchenko, N. Hohadze, AP Hartvyh, IV Feofylov* (USSR). - №3844027; appl. 20/11/84; publ. 7.2.87. Bull. Number 15.
10. AS 1347602 USSR, MKY3 F 02 B 43/00. Method vnutrenneho combustion engine work / *Dolynskyy AA, AI Gurov, IV Feofylov* (USSR). - №4020981; appl. 02/12/86; publ. 7.8.87. Bull. Number 39.



*Conducted analysis raznыh koheneratsyonnыh typical installations from the point of view naybolshey эkonomyy fuel, brought Comparison suschestvuyuschyh sposobov additions of water for the fuel-air mixture in combustion engines and abilities Showing Increase of the effectiveness koheneratsyonnoy settings based ICE for schet uvlazhnenyya dutevoho air.*



***Kogeneratsionnaja installation, additions of water for fuel, kondensatsyonnыe utylyzatorы teplotы.***



*The analysis of different types of cogeneration settings from point of most economy of fuel is conducted, comparison of existent methods of addition of water to fuel-air mixture in combustion engines is cited and possibility of increase of efficiency of the cogeneration setting on the basis of combustion engine on account of moistening of air are showed.*



***Cogeneration setting, addition of water to fuel, heat condensation settings.***