11^{th} International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

EXERGY ANALYSIS OF USE OF NATURAL GAS SUPPORTED HYDROGEN IN CONDENSING COMBIES

Kemal Altinişik*, Dilek Nur Özen*, Şeçil Şirin* , Şenay Yalçin, Alper Altinişik*****
*** Selcuk University, Engineering Faculty, Konya , Turkey**
**** Bahcesehir University , Engineering Faculty, Istanbul, Turkey**
***** Uzel Machine Ind. , Istanbul , Turkey**

ABSTRACT

The condensing combies run according to recyling of waste heat thrown away from the chimney. The natural gas as fuel is used in combies. The temperature of stack gas is holded less than 55 ^0C *, and the water in stack gas condenses. The condensing water is approximately 50* ^0C *is electrolysed and the hydrogen obtained in result electrolyse is given into the natural gas as support In this study, the exergy analysis of such a system was done. Because of irreversibility, the availability joining into the burning process is decreases in ratio 22% Before using the thermal energy, 22% of work potential is lost during the burning of natural gas supported hydrogen. It has been that the efficiency of exergy is proportional with the increase in exergy of heated water.*

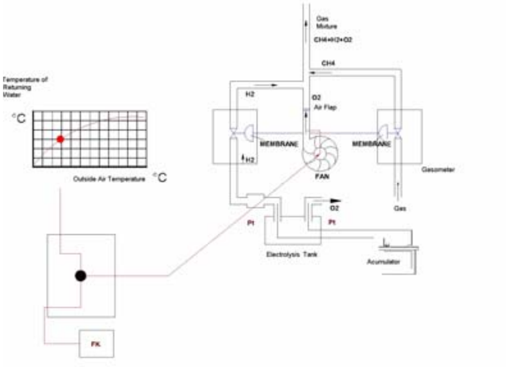
Keywords: Exergy analysis, Natural gas, Condensing combie

1. INTRODUCTION

In the present day, energy sourches rapidly give out, and the air pollution problem has been growing up from day to day. At the same time, the present energy sourches gradually come to an end. In addition, the increase of the world global temperature is very important for invironment problems. In order to decrease to the air pollution and to increase the efficiency of the burning system, the condensing systems are used in this field. Because of use of waste heat, condensing systems are known for along time. Condensing combies which are one of these systems are used in small residences.

Haas, F., and others (1) have stated that there are acid compounds in stack gas and if the temperature of stack gas reaches up the dew point temperature, the acid compounds is absorbed by condensing water. Because of corrosive specification of condensing water, it affects on to the material. In order to notralize the acid in stack gas, the stack gas has to be cooled under dew point temperature in natural conditions. Kuek, J., (2) has studied to evaluate the sensible heat of hydrogen and water vapour in stack gas and he has pointed out that it is possible to use the sensible heat of vaporization in high temperature. Che, D.; and others (3) has stated if the sensible heat of vaporization is used in the condensing heat exchangers, the efficieny of the system increases at least 10%. Renato, M., and others (4) have expressed that the behaviour of condensing combies is dependent to the temperature of returning water from the system, and the temperature of the returning water changes with the meteorologic conditions. Magri, G., and others (5) used three way valve for adjustment of hot water coming from the heat exchanger and heating cycle. Dinçer and others (6) stated that the environment dirtness affected to the eco system. Simonson, C.J., and others (7) have expressed that it is necessary to use the searches having the low energy value instead of searches having the high energy value. and they have proposed to use the low exergy solutions and the strategies for cooling in buildings. The exergy efficiency and losses were examined by Nikulshin, V., and others (8), and they pointed out the relation between sub-elements of and total system. They stated that the powered mathematical model was developed in this field. The mathematical model was developed by Rzayeva, M.P., and other (9), for production hydrogen and oxygen from water under perssure. They propered the block scheme and software of the system.

In this study, the exergy analysis of the use as fuel of the natural gas supported the hydrogen in combies has been done. The principle schema of the condensing comby containg electrolys vessel was shown in Figure 1.



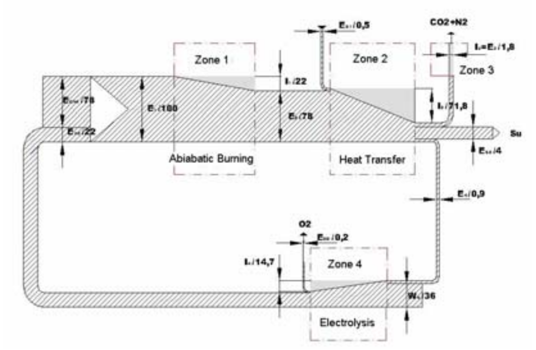


Figure 1. Condesing comby containing electrolysis tank

Figure2. The exergy graph of the system

The temperature of water obtained from the condensig of water vapour is more than 50^{0}C. The condensing water collects into the electrolysis tank and water is electrolysised, to obtain the hydrogen. It is mixed with the natural gas. Rectifier is used for changing the alternative current to the direct current in electrolysis of water.

2. THEORY

The maximum work of the system is obtained, when the system is brought from a certain beginning with changing reversible state to the environmental conditions. This value is defined as exergy. The exegry graph of the system is shown in Figure 2. For the exergy analysis, the exergy graph is divided into the 4 parts. The first one is adiabatic burning zone, second one is zone where the heat is transferred, third one is zone in which the products in the end of the burning trow away, and the fourth one is zone in which the electrolysis process is realized.

The adiabatic flame temperature of burning process (10) is,

$$H_{yiç} = H_{yig} \tag{1}$$

or

$$Q = \sum n_ç (\bar{h}_f{}^o + \bar{h} - \bar{h}^o)_ç - \sum n_g (\bar{h}_f{}^o + \bar{h} - \bar{h}^o)_g \tag{2}$$

The formation anthalpies of the stabl elements are zero, because of this, equation (2) can be written as follows

$$Q = \sum n_ç (\bar{h}_f{}^o)_ç - \sum n_g (\bar{h}_f{}^o)_g \tag{3}$$

Here, the sub-heat value of fuel is (Q).
Irreversibility for zone 1 (11) is

$$E_1 = E_F - E_2 \tag{4}$$

Where, E_F is the exergy of fuel and it can be stated in the following form,

$$E_F = n_{CH_4} \cdot \overset{o}{\varepsilon}_{CH_4} \tag{5}$$

The exergy of products in the end of burning is

$$E_2 = n_{P2} \cdot \overset{o}{\varepsilon}_{P_2} + \sum_k n_k \, \varepsilon_{ph,k} \tag{6}$$

$\overset{o}{\varepsilon}_{P_2}$ is chemical exergy of burning products in inlet to the zone 2 and it is written in the following form.

$$\overset{o}{\varepsilon}_{P_2} = \sum_k X_k \cdot \overset{o}{\varepsilon}_k + R_u.T^o.\sum_k X_k \, \text{In} X_k \tag{7}$$

For the physical exergy in following equation can be expressed

$$\sum_{k} n_k\, \varepsilon_{ph,k} = (T_2 - T_o) \sum_{k} n_k .c_p^{\varepsilon},_k + R_u .T_o\, \mathrm{In}(P / P_o) \tag{8}$$

If $P = P_0$, in this case, equation (8) can be rewritten in the following form

$$\sum_{k} n_k\, \varepsilon_{ph,k} = (T_2 - T_o) \sum_{k} n_k .c_p^{\varepsilon},_k \tag{9}$$

Irreversibility for zone 2 is

$$I_{II}=[E_2-(E_3+E_4)]-(E_{s2}-E_{s1}) \tag{10}$$

and amount of heated water can be given as follows

$$m_s = \frac{(H_2 - H_3 + Q_{gizli})}{(h_2 - h_1)} \tag{11}$$

Entalphy of products in the end of burning in inlet to the zone 2 is

$$H_2 = (T_2 - T_o) \sum_{k} n_k\, C_p^{h},_k \tag{12}$$

and entalphy for zone 3 is

$$H_3 = (T_3 - T_o) \sum_{k} n_k\, C_p^{h},_k \tag{13}$$

The condensing heat of water vapour in stack gas is

$$Q_{gizli} = n_{H_2O} .\bar{h}_{fg} \tag{14}$$

Fort he increase in exergy of heated water, the following equation can be written

$$E_{s_2} - E_{s_1} = m_s \left[(h_2 - h_1) - T_o (s_2 - s_1)\right] \tag{15}$$

The exergy of products in the end of burning in inlet to the zone 3 is

$$E_3 = E_3^{o} + (E_{ph})_3 \tag{16}$$

Where, E_3^{o} is chemical exergy and it can be stated in the following form

$$E_3^{o} = n_{p_3} \left[(\sum_{k} X_k \cdot \varepsilon_k^{o}) + (R_u .T_o . \sum_{k} X_k\, \mathrm{In}\, X_k) \right] \tag{17}$$

$(E_{ph})_3$ is physical exergy and it is given by equation (18),

$$(E_{ph})_3 = (T_3 - T_o) \sum_{k} n_k\, c_{p,k}^{\varepsilon} R_u T_o\, \mathrm{In}(P / P_o) \tag{18}$$

If P equals to the P^{o}, in this case, the equation (18) is rewritten as follows,

$$(E_{ph})_3 = (T_3 - T_o) \sum_{k} n_k\, c_{p,k}^{\varepsilon} \tag{19}$$

The exergy of the condensing water is

$$E_4 = n_{H_2O} \left[\varepsilon_{H_2O}^{o} + (\bar{h}_f - \bar{h}_{f_o}) - T_o (\bar{s}_f - \bar{s}_{f_o}) \right] \tag{20}$$

Irreversibility equals to the exergy in the zone 3, because, the products in the end of burning is thrown away without using in zone 3.

The irreversibility for zone 4 is

$$I_{IV} = (E_4 + W_{elk}) - (E_{H_2} + E_{O_2}) \tag{21}$$

and the total exergy is

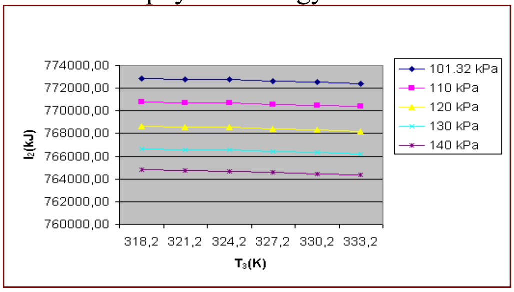
$$E_{H_2} + E_{O_2} = n_{H_2} \cdot \varepsilon_{H_2}^{o} + n_{O_2} \cdot \varepsilon_{O_2}^{o} \tag{22}$$

The exergy efficiency of whole system can be expressed in the following form

$$\eta = \frac{E_{s_2} - E_{s_1}}{E_{CH_4} + W_e} \tag{23}$$

3. CONCLUSION

The numerical calculations have been done by utilizing from the theoretical approaches, and it has been seen that the availability of the thermal energy is decreased in ratio of 22 %, because of irreversibility in burning process. As shown in Figure 3 when the inlet temperature of the products in the end of burning increases, the value of irreversibility changes according to temperature T_3 at the same pressure. Because the value of physical exergy increases.



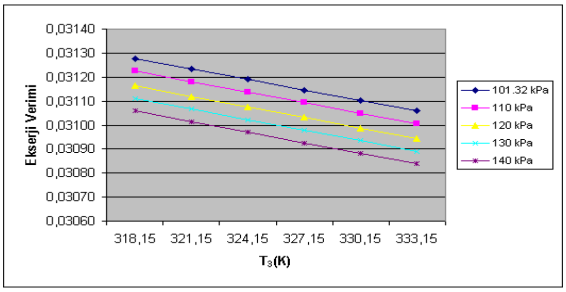


Figure 3. According to temperature of T_3 the change *Figure 4. According to the temperature of*
T_3 , the change of irreversibility value *of exergy efficiency*

Figure 4 shows that the inlet temperature into the zone 3 increases, the exergy efficiency decreases. Because, the heat given to the water decreases. According to thermodynamic's second law, it is possible to change into the work, the chemical enegry with an effective way. The effective way is certainly the way which the irreversibility is less. The irreversibility becomes uncontrolled electrons. The exchange between uncontrolled electrons causes the irreversibility in chemical reactions. The electron exchange can be controlled by changing with the electronic cell the burning room. The electron exchange comes true by the agency of the conductive wires depending the load and the chemical energy directly return into the electrical energy

4. REFERENCES

[1] Haas, F., Koehine, H., Design of Scrubbers For Condensing Builers, Progress, in Energy and Combustion Science, 25, 305-337, 1999.
[2] Kuck, J., Efficiency of Vapour-Pump-Equipped Condensing Boilers, Applied Thermal Engineering, V. 16, Issue 3 233-244, March, 1996.
[3] Che, D., Liu, Y., Gao, C., Evaluation of Retrofitting a Conventional Natural Gas Fired Boiler into a Condensing Boiler, Energy Convension and Management, 45, 3251-3266, 2004.
[4] Renato, M., Lazzarin and Luigi Schibuola, Performance Analysis of Heating Plants Equipped with Condensing Boilers, Journal of Heat Recovery Systems, V. 6, Issue 4, p. 269-276, 1986.
[5] Magri, G., Romagnoli, M., Di Perma, C., (5), SMA Actuator for Gas Combi Boiler Diverting Value, Sansors Actuators A 128, 355-366, 2006.
[6] Dineer, I., Rosen, M.A., On Exergy and Environmental Impact, V. 21, Issue 7, p. 643-654, 1998.
[7] Simonsen, C.J., and Leskinen, M., Low Exergy Systems for Heating and Cooling of Buildings, IEA Energy Concervation in Buildings and Community Systems, 5th Joint Meeting of ECBCS and SHC executive commitiees, Bordeaux, France June 13, 2001.
[8] Nikulshin, V., Boiley, M., and Nikolshina, V., Thermodynamic Analysis of Air Refrigeration on Exergy. Graph, Thermal Science, V. 10, No: 1, pp. 99-110, 2006.
[9] Rzayeva, M.P., Salamov, O.M., Kerimov, M.K., Modeling to Get Hydrogen And Oxygen By Solar Water Electrolysis Int. J. Hydrogen Energy, 26; 195-201, 2001.
[10] Çengel, Y.A., Boles, M.A., Termodinamik, McGraw-Hill, NewYork, 1996.
[11] Kotas, T.J., The Exergy Metod of Thermal Plant Analysis,Butter Worths, London, 1985.