EXERGETIC EFFICIENCY OF HIGH POWER THERMOACOUSTIC PLANT

Dan ANDREI*

*UNIVERSITY ”DUNAREA DE JOS “ , Galati, Romania

Rezumat. Determinarea expresiei matematice a randamentului exergetic al masinii termoacustice combinate de mare putere, care cupleaza un generator de unde (motor termoacustic) cu un amplificator de unde, da posibilitatea vizualizarii parametrilor asupra carora putem actiona pentru marirea acestui randament.
Cuvinte cheie: randament exergetic, motor termoacustic, masina termoacustica combinata de mare putere

Abstract. The exergetic efficiency of high power thermoacoustic plant, which couples a wave generator (thermoacoustic engine) with wave amplifier, shows the way we can increase the efficiency.
Keywords: exergetic efficiency, thermoacoustic engine, high power thermoacoustic plant

1. INTRODUCTION

The high power thermoacoustic plant (fig. 1) consists of a couples from a thermoacoustic engine (wave generator) with wave amplifier.

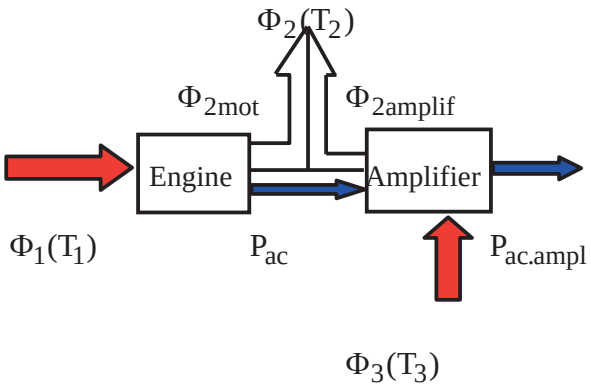

Fig. 1. High power thermoacoustic plant

The goal is to amplify the wave from thermoacoustic engine in order to obtain a higher power than the output of engine.

The equation of I Principle of Thermodynamics [1], [4], [5], is :

$$\Phi_1 + \Phi_3 - |\Phi_2| - P_{ac_amplif} = 0\,; \qquad (1)$$

where :

$$\Phi_2 = \Phi_{2mot} + \Phi_{2amplif}\,. \qquad (2)$$

The equation of II Principle of Thermodynamics is :

$$\dot{S}_{gen_ciclu} = -\frac{\Phi_1}{T_1} + \frac{|\Phi_2|}{T_2} - \frac{\Phi_3}{T_3} \geq 0\,. \qquad (3)$$

In the case, of the high power thermoacoustic combined plant, the engine follows the Brayton cicle (2 adiabates and 2 isobares) [1], [2], [3], [4], [5] and the wave amplifier follows Ericsson cicle (2 isothermals and 2 isobares) [1], [2], [3], [4], [5].

2. CARNOT AND EXERGETIC EFFICIENCIES

The Carnot efficiency of combined plant which works between the some temperatures is :

$$\eta_{Carnot_MC} = \frac{P_{ac_amplif}}{\Phi_1 + \Phi_3} = 1 - \frac{|\Phi_2|}{\Phi_1 + \Phi_3}\,;$$

$$\eta_{C_MC} = 1 - \frac{\dfrac{|\Phi_2|}{\Phi_1}}{\left(1 + \dfrac{\Phi_3}{\Phi_1}\right)} = 1 - \frac{\dfrac{T_2}{T_1} + \dfrac{\Phi_3}{\Phi_1}\cdot\dfrac{T_2}{T_3}}{\left(1 + \dfrac{\Phi_3}{\Phi_1}\right)};$$

or

$$\eta_{C_MC} = 1 - \frac{\left(1 - \eta_{C_mot}\right) + \dfrac{\Phi_3}{\Phi_1}\cdot\left(1 - \eta_{C_amplif}\right)}{\left(1 + \dfrac{\Phi_3}{\Phi_1}\right)}; \qquad (4)$$

where :

$$\eta_{C_mot} = 1 - \frac{T_2}{T_1} \; ; \qquad (5)$$

and

$$\eta_{C_amplif} = 1 - \frac{T_2}{T_3} . \qquad (6)$$

Exergetic efficiencies of engine, amplifier and combined plant when environmental temperature is equal to low temperature ($T_{amb} = T_2$), is :

$$\eta_{ex_mot} = \frac{P_{ac}}{\Phi_1\left(1 - \frac{T_{amb}}{T_1}\right)} ; \qquad (7)$$

$$\eta_{ex_amplif} = \frac{P_{ac_amplif} - P_{ac}}{\Phi_2\left(1 - \frac{T_{amb}}{T_3}\right)} \; ; \qquad (8)$$

$$\eta_{ex_MC} = \frac{P_{ac_amp}}{\Phi_1\left(1 - \frac{T_{amb}}{T_1}\right) + \Phi_3\left(1 - \frac{T_{amb}}{T_3}\right)} =$$

$$= \frac{P_{ac_amp}}{\Phi_1\left[\left(1 - \frac{T_{amb}}{T_1}\right) + \frac{\Phi_3}{\Phi_1}\left(1 - \frac{T_{amb}}{T_3}\right)\right]} =$$

$$= \frac{P_{ac_amp}}{\frac{P_{ac}}{\eta_{C_mot}}\left(\eta_{C_mot} + \frac{\Phi_3}{\Phi_1}\eta_{C_amplif}\right)} ; \qquad (9)$$

or

$$\eta_{ex_MC} = \frac{\frac{P_{ac_amp}}{P_{ac}} \cdot \eta_{C_mot}}{\eta_{C_mot} + \frac{\Phi_3}{\Phi_1} \cdot \eta_{C-amplif}} . \qquad (10)$$

If we name:

$$\beta = \frac{P_{ac_amplif}}{P_{ac}} \; ; \qquad (11)$$

the magnifier coefficient of plant, the exergetic efficiency of combined high power plant is :

$$\eta_{ex_MC} = \frac{\beta \cdot \eta_{C_mot}}{\eta_{C_mot} + \frac{\Phi_3}{\Phi_1} \cdot \eta_{C-amplif}} . \qquad (12)$$

3. CONCLUSIONS

We notice the exergetic efficiency of combined high power plant increase with the increase of magnifier coefficient β.

REFERENCES

[1] Dan ANDREI, George ANDREI – *Thermoacoustic engines*, Analele Universitatii "Dunarea de Jos" din Galatii, fascicula IV ISSN 1221-4558 pag 181-184 (2005);

[2] George ANDREI, Dan ANDREI – *A new thermodinamic concept: thermoacoustic refrigerators*, Analele Universitatii "Dunarea de Jos" din Galatii, fascicula IV ISSN 1221-4558 pag 7-10 (2005);

[3] George ANDREI, – *Studii acustice si termice ale schimbatoarelor de caldura din sistemele termoacustice*, teza de doctorat, Universitatea "Dunarea de Jos" din Galatii, 2008;

[4] George ANDREI, Dan ANDREI – *A new thermodinamic concept: thermoacoustic engines*, The 30th Anual ARA Congress, July 5-10, Chisinau, Republic of Moldova, pag 475-478, ISSN 9975-75-313-2(2005);

[5] Adrian Bejan – *Advanced Engineering Thermodinamics*, Wiley, second edition, (1997).