

Vladimír KOCÚR\*, Jozef ŠURIANSKY\*\*

SIMULATIONS AND MODELLING OF ABSORPTION COOLING UNIT BY MEANS  
OF PELTIER MODULE

SIMULÁCIE A MODELOVANIE ABSORPČNEJ CHLADIACEJ JEDNOTKY POMOCOU PEL-  
TIEROVHO MODULU

**Abstract**

Article refers to function of absorption cooling unit simulated by means of Peltier module. Although, this system works on entirely different physical principle, it is necessary to use it as equivalent of absorption cooling what is proved in more detail in article.

**Abstrakt**

Článok poukazuje na činnosť absorpčnej chladiacej jednotky simulovanej pomocou Peltierovho modulu. Hoci tento systém pracuje na úplne odlišnom fyzikálnom princípe, je možné ho použiť ako ekvivalent absorpčného chladenia, čo je bližšie dokázané v článku.

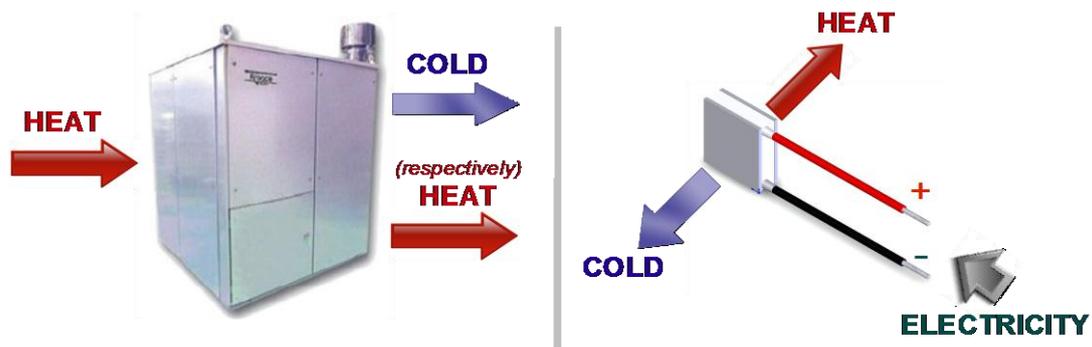
**1 INTRODUCTION**

Absorption cooling unit (ABCU) is system which is often used in trigeneration by which we can transform produced heat to cold by absorption principle. However, this system can work in heating mode instead of cooling mode. Power series of absorption coolers are in tens to hundreds of kW-atts, wherein their price and size are often the main disadvantages, which prevent from experiments. So we selected for the aim of our research finding of similar device, which would replace absorption cooling unit for purpose of simulations, modelling and experiments. We selected a Peltier module as a device, which would be able to produce cold, which would be affordable and also acceptable in terms of sizes and suitable as equivalent of absorption cooling at the same time. This element works with using of Peltier effect on basis of which it comes to creating of temperature difference on links of two connected semiconductors by means of fed electric current. Powers of these systems are (unlike of ABCU) in tens to hundreds W-atts. It can be seen, that both systems of heat production work on different physical principles, wherein input of ABCU is thermal energy and output cold (respectively heat) and in the case of Peltier module input is electrical energy and output cold (on one side of module) and heat (on other side of module). Despite of clear differences of described systems, there is similarity between mathematical models of systems. This similarity can be proved on the basis of comparison of their outputs characteristics. The representation of their energetical flows is shown on the (Fig.1).

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\* Ing. Vladimír KOCÚR, Technical university in Zvolen, Faculty of Environmental and Manufacturing Technology, Department of Informatics and Automation Technology, 24 T. G. Masaryk Street, 960 53 Zvolen, Slovakia, e-mail: [xkocurv@is.tuzvo.sk](mailto:xkocurv@is.tuzvo.sk)

\*\* prof. Ing. Jozef ŠURIANSKY, CSc., Technical university in Zvolen, Faculty of Environmental and Manufacturing Technology, Department of Informatics and Automation Technology, 24 T. G. Masaryk Street, 960 53 Zvolen, Slovakia, e-mail: [surian@vsld.tuzvo.sk](mailto:surian@vsld.tuzvo.sk)



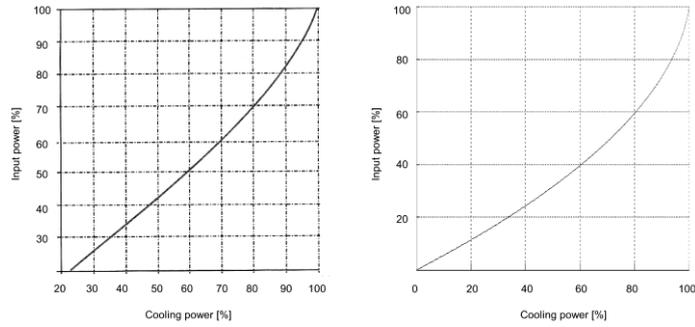
**Fig. 1** Representation of systems energetical flows of: absorption cooling unit (left) and Peltier module (right).

## 2 MATHEMATICAL PROOFS OF ABCU AND PELTIER MODULE SIMILARITY

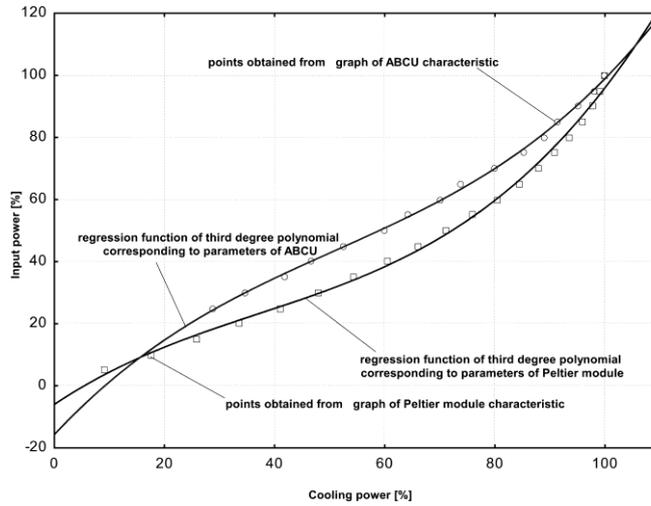
To prove mathematical similarity between described systems we tested similarity based on regression analysis of mathematical models. We went out from comparison of output dependences of ABCU obtained from literature [1] and [4] with dependences of Peltier module which we simulated by use of known mathematical model [2] in program MatlabR2006a. Because input energies are in their nature different sorts of energy, in both systems we took them for input energies (or powers) only in general and we calculated them into percents, what didn't degrade character of dependences [6]. From these graphs data were obtained from which regression functions of both systems were calculated based on selected equation, which is used by modelling of one of them. For this purpose equation was selected – 3rd degree polynomial, by which Peltier module is modelled. Comparisons of mathematic models were carried out in program Statistica 7. Procedure consisted in obtaining data from characteristics of ABCU and of Peltier module and using of selected equation of 3rd degree polynomial and then regression curves were created in program. In the first step of comparison we were finding out, if selected equation meets obtained data. In the second step we were finding out, if these curves have the same general features. That means, it was researched, if points set by us from Peltier module graph generate such model parameters (created by selected 3rd degree polynomial), which would be similar to model parameters generated by points obtained from ABCU graph. By means of Two-Sample Student's t-test of identity of individual parameters of regression functions, which compares parameters with standard error of parameter estimation on given confidence interval, identity of parameters of individual functions was evaluated. By means of One-Sample Student's t-test, which on the other hand compares concrete parameter with zero, significance of regression functions parameters was evaluated.

It is possible to summarize tests into following points:

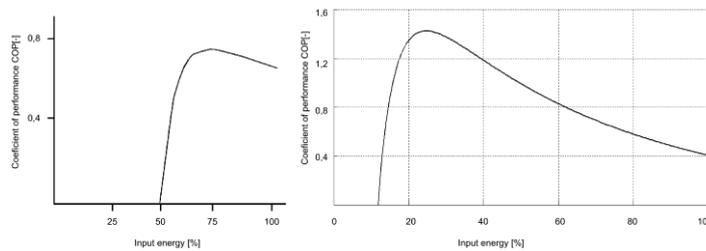
- a) testing of suitability of regression functions for obtained values from graphs,
- b) testing of parameters significance of compared regression functions,
- c) testing of signs identity of individual parameters of compared regression functions,
- d) testing of identity (numerical correspondence) of individual parameters of compared regression functions.



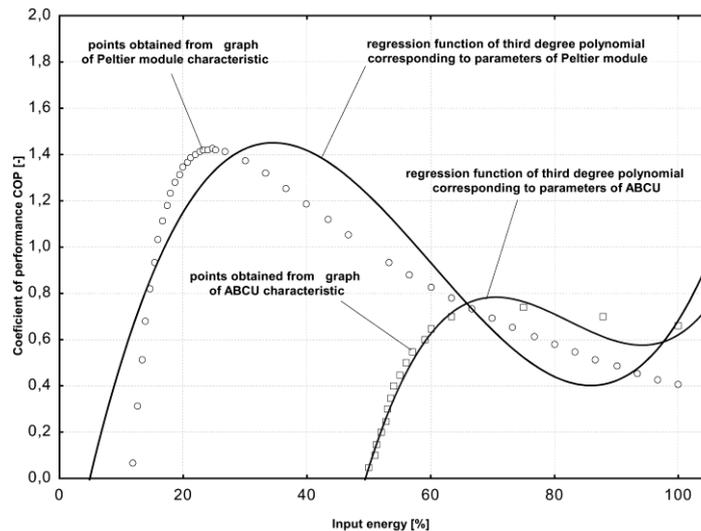
**Fig. 2** Dependences of input and output powers of:  
 ABCU based on LiBr [1] (left) and Peltier module / $T_c = T_h = 25^\circ\text{C}$ / (right)  
 (\* $T_c$  – temperature of cold side and  $T_h$  – temperature of hot side of Peltier module).



**Fig.3** Regression functions calculated in program Statistica corresponding to dependences in (Fig.2) and to selected 3rd degree polynomial.



**Fig. 4** Dependences of coefficient of performance on input energy of:  
 ABCU based on LiBr [2] (left) and Peltier module / $T_c = 25^\circ\text{C}$ ,  $T_h = 45^\circ\text{C}$ / (right).



**Fig. 5** Regression functions calculated in program Statistica corresponding to dependences in Fig.4 and to selected 3rd degree polynomial.

### 2.1 Tests results

- a) Testing of suitability of regression functions for obtained data from graphs – it was showed in both cases of tests, that selected equation of 3rd degree polynomial is suitable for modelling of researched systems on given observed interval.
- b) Testing of significance of parameters of compared regression functions – it was proved with verification of parameters significance of both systems, that all parameters are statistically significant (so they are not neglectable) apart from one case when parameter of absolute element was on the edge of importance [5].
- c) Testing of signs identity of individual parameters of compared regression functions –it was found out with comparison of parameters, that signs of parameters of systems regression functions are significantly the same (and in both systems they are in concrete case of parameters either positive or negative), however, they are different in sizes and numbers. The result is, that equation has the same character with the same quality of parameters in ABCU as well as in Peltier module.
- d) Testing of identity (numerical correspondence) of individual parameters of compared regression functions – identity of all compared parameters was confirmed in the first comparison of dependences (Fig.3) and for the second comparison (Fig.5) the identity was not proved.

Based on these results we can say that, compared systems ABCU and Peltier module (even if their parameters were not identical) are modelled similarly, so they are similar. In addition, obvious common element of systems, which refers to their similarity is the same shape of curves of the output characteristics.

Based on this knowledge, we can continue in simulation and experiments, by means of which it can be possible to watch and document very elegantly behaviour of absorption cooling unit by use of Peltier module.

### 3 SIMULATIONS OF ABCU BY MEANS OF MATHEMATICAL MODEL OF PELTIER MODULE

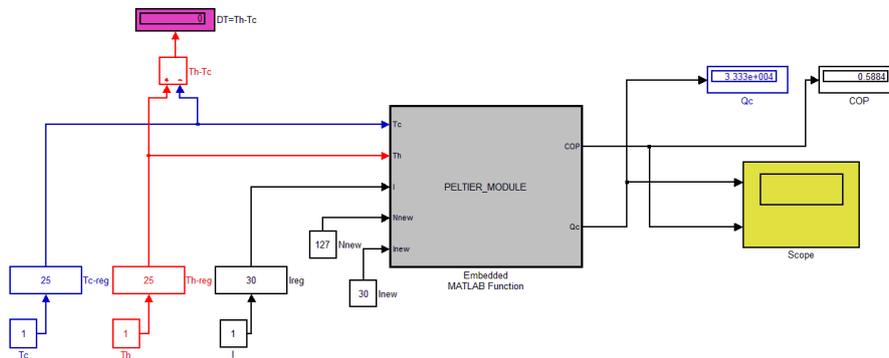
As it was marked in introduction, there is great difference between rates of powers of described systems. So it is necessary to work in scale, by which we could approach to powers achieved by ABCU by means of Peltier module simulations. We are thinking of using 33 kW-atts absorption unit and Peltier module with output power 267 W for simulations of absorption cooling unit, which will be simulated by equivalent module. So for simulation we select approximate scale 1:130.

#### 3.1 Simulations aim and tasks

Aim of our simulations was set of power of produced cold of absorption cooling unit by means of use of Peltier module. We selected two significant tasks for fulfilment of this requirement:

1. simulation model must work in scale 1:130 (ABCU:Peltier module),
2. possibility of direct influence of resultant produced cold during simulation by means of input value and of temperature different between two sides of module.

#### 3.2 Simulation model



**Fig. 6** Simulation model of Peltier module as equivalence of absorption cooling unit created in program background Matlab/Simulink.

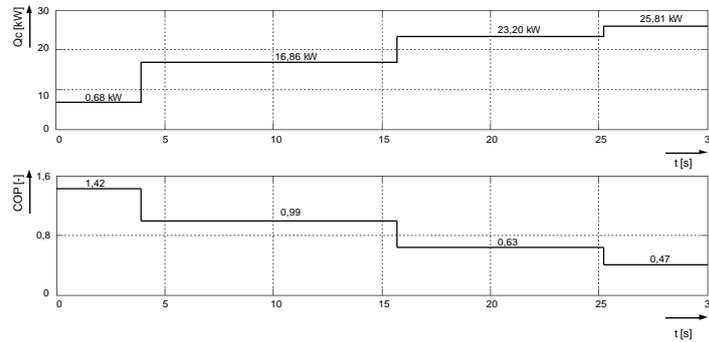
Simulation model of Peltier module goes out from known mathematical model [2]. Model allows entering of value of input variable and temperature difference between hot and cold side of Peltier module by means of entering of temperatures  $T_h$  and  $T_c$ . Entered values can be elegantly changed by means of sliders directly during the run of simulation. Actual cooling power as well as calculated coefficient of performance can be watched directly on digital indicators and showed on scopes, too. Model can be displaced for different types of Peltier modules, as it is possible to change its parameters by means of change of semiconductor pairs number and input current.

#### 3.3 Simulations results

In program\_Matlab simulations of following outputs parameters were made:

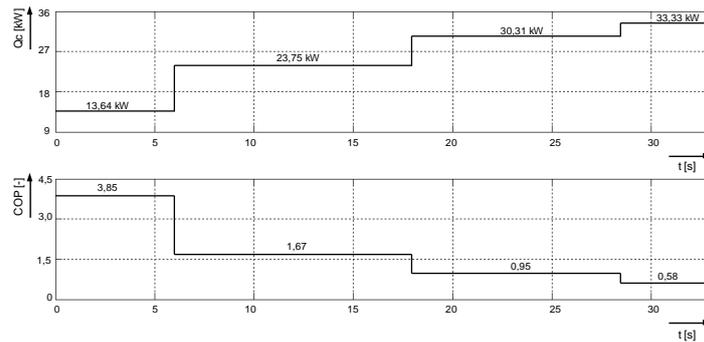
- cooling power  $Q_c$  [kW],
- coefficient of performance COP [-] corresponding to produced cold; coefficient of performance is one of the most important parameters necessary to assessment of energetical systems. Coefficient of performance COP is in this case related to input value by which is set ratio between energy (respectively power) obtained from system and energy brought into system is set.

We simulated researched variables in dependence on time, wherein in individual time relations during simulation impacts were made into system by means of step change of input variable. We selected 25 % of input variable for initial state then we increased it to 50 %, 75 % and 100 %. We made one simulation for temperature difference between cold and hot side of Peltier module 20°C (see Fig.7).



**Fig. 7** Display of simulated values of cooling power  $Q_c$  and coefficient of performance COP of Peltier module for step changes of input variable (25 %, 50 %, 75 % and 100 %) and for temperature difference  $T_h - T_c = 20\text{ }^\circ\text{C}$ .

Since Peltier module system has full power in zero temperature difference, we made simulations also for this temperature change. Results of simulations for zero temperature difference are shown on (Fig. 8).



**Fig. 8** Display of simulated values of cooling power  $Q_c$  and coefficient of performance COP of Peltier module for step changes of input variable (25%, 50%, 75% and 100%) and for zero temperature difference  $T_h - T_c$ .

#### 4 CONCLUSION

For execution of absorption cooling unit experiments it is preferred to use Peltier module. This element is appropriate equivalent of cooling unit in terms of price, sizes or its own simplicity. In the second chapter were marked proofs of mathematical similarity of systems ABCU and Peltier module based on it can be use of Peltier element for mentioned purposes. Based on known mathematical model a simulation model of Peltier module was created for execution of simulations, which works in appropriate scale 1:130. This scale was selected on the basis of consideration of ABCU with maxi-

mum power 33 kW and of Peltier module with power 267 W. By means of simulation model courses will be obtained, by which it can be possible to watch behaviour of ABCU in different conditions of system operation.

Research described in this article is important step for creating of regulation algorithms which are necessary to optimize trigeneration system control.

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