ENERGY EFFICIENCY OF THE MODULAR PROCESS ELECTRIC HEATERS
ENERGETSKA EFIKASNOST MODULARNIH PROCESNIH ELEKTRIČNIH GRIJAČA

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Keywords: process electric heater, adaptive process heater, energy efficiency, adaptive heating elements

ABSTRACT:

In this the work presented and analyzed the innovative solution of the adaptive electric heater designed to heat compressible fluids. This electric heater consists of several series-connected heating elements with different electric power. These heated elements can vary positioned in relation of the compressible fluid flow through the adaptive heater. The total power of the adaptive heater is 756 W, while the electric power of heating elements varied with the 38W, 54W and 70W. Volumetric air flow variations in the amount of $0.001 m^3 s^{-1}$ *and* $0.003\ m^3 s^{-1}$*. The heating elements positioned in the three combinations, A, B and C in relation to the direction of the air flow. The comparative numeric analysis, conducted in this work, has the goal to determine the influence of arrangement of heating elements to the overall energy efficiency of the adaptive electric heater.*

Ključne riječi: procesni električni grijač, adaptivni procesni grijač, energetska efikasnost, adaptivni grijni elementi

SAŽETAK:

U ovom radu je prezentirano inovativno rješenje adaptivnih električnih grijača kompresibilnih fluida.Ovaj tip električnog grijača sastoji se od nekoliko serijski povezanih grijnih elementa, različitih pojedinačnih snaga. Grijni elementi mogu biti različito pozicionirani u odnosu na smjer strujanje kompresibilnog fluida kroz adaptivni zagrijač.Ukupna snaga adaptivnog grijača je 756 W dok su pojedinačne snage grijnih elemenata varirane od 38W, 54W i 70W. Volumetrijski protok zraka variran je u vrijednostima $0.001 m^3 s^{-1}$ *i* $0.003\ m^3 s^{-1}$*. U tri kombinacije A,B i C pozicionirani su elementi u odnosu na smjer kretanja zraka. Korištenjem komparativne numeričke analize u ovom radu imalo je za cilj utvrditi uticaj aranžmana grijnih elementa na efikasnost ukupnog adaptivnog grijača.*

1. INTRODUCTION

For convective heating of the compressible and incompressible fluids used a large number of process heaters. The most process heaters the heat generated by conversion from electrical energy.

Convectively heating of the air or gas can carry at normal atmospheric pressure or under high pressure. The heating of the compressible fluid under atmospherical pressure includes a channel within which installed the electric heater. Heating of the compressed fluid additional includes a compression system and using electric process heaters. Fluid flows through the convection heating surface, while the forced convection this fluid heated with different intensity. Wide field through the application these process heaters, so heat used to clean, dry air orgasm for baking, drying, laminating, metalworking, packaging, plastic welding, preheating, sealing, soldering, etc. Many technical factors influence upon the efficiency of the process electric heaters, i.e. The electricity used to heat the fluid. The fluid velocity, the temperature of the convective surfaces and the geometric architecture of the channel for the passage of the fluid are significantly affected by the process heating efficiency. One of the frequencies used electric heaters of this type is the band heater, with efficient and economical heating the outer surface of the pipe through which fluid flows. These heaters can produce with a ceramic housing if they want to achieve a high temperature. A.A. Rezwan et al.[1] studied air process heater with the numerical simulation values of the designed heater. The results also compared with some of the existing air process heaters. Abbas T,.Carmel M.,and Wanliang S., [2] Investigated thermal parameters of internal Joule heaters with measurements, surface temperature distributions during a Joule heating process. F. Alic [3,4] analyze an innovative way of heating fluid or nanofluid and entrance dissipation ratio using an adaptive electric heater consisting of three hollow cylindrical heating elements. In the context of previous research and disadvantages of the existing process, heaters proposed an innovative solution, called adaptive heat source. The technical novelty of this idea based on the creation of the process electrical power heater consisting of the several independent heating elements. Electrically heated elements combined with each other and thus provide requesting the total power over the process of the electric heaters.

2. ADAPTIVE PROCESS HEATING OF THE COMPRESSIBLE FLUID

Convective heating of the fluid flow realized over and within the different heating surfaces. Heating of the surface can achieve through the conversion of the electrical energy, which analyzed for this paper. The present solutions to the process convective heater for compressible fluid, shown in Fig.1. The air flow, pressure $p_{a.in}$ and temperature $t_{a.in}$, entrance to the convective process heater on section A, and exits at section B, pressure $p_{a.out}$ and temperature $t_{a.out}$, Fig.1. The air flows over the electric heater surface and heated, $t_{a.in} < t_{a.out}$, while the air pressure within the heater decreases the value of $dp_a = p_{a.in} - p_{a.out}$. The air within the process heater, heated gradually, thus reducing the difference inter the temperature of heating surface and air. Decrease of this temperature difference reduces the heat flux exchanged between the heater and the air. With the decrease of temperature difference, reduces the heat flux exchanged inter the heater and the air.

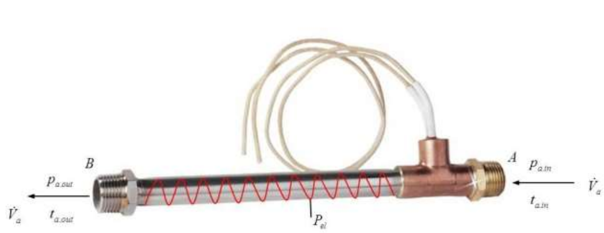

Figure 1: Process heater for in-line air and gas heating

For gas or air, heating is to use an open coil heater, which allows the air stream to make direct contact with the heater element improving the heat transfer, Fig.1. The heating surface, Fig.1, the most common placed across the channel within which air flows or any other incompressible fluid, which can heat. On the other hand, the basic elements of the heating surface represent the continuous heater, generally made of the electric resistance wires. The resistance wire heating, so that any damage to wire caused termination of heating fluid. Possible repair of the damaged heater like this is rare, main for the installed new process electric heater. In order to eliminate these technical problems need for designing the adaptive process heaters of the compressible fluid. The central part of the process heater is an independent element, Fig. 2.

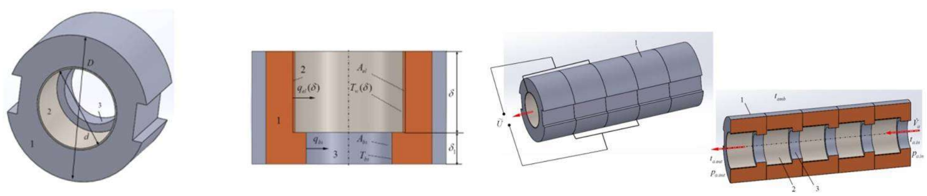

Figure: 2 The adaptive heating electric element and serial configuration of the adaptive heating elements

Figure 2 shows one of the possible forms of the adaptive heating elements (AHE), which investigated in this study. This element consists of the cylindrical base 1 and of the heated ring 2. Mounting of the AHE, in order reach the required power over the process of the electric heater shown in Fig. 2.

3. RESULTS AND DISCUSSIONS

The research conducted in this paper based on a study of three cases of combined arrangement of adaptive heating elements of the convective process heaters. The total power of the process heater is 756W, while the number of adaptive heating elements is 14. Adaptive heated elements, according to Figure 2, placed in serial connection and simultaneously connected to an external electric voltage of 220V. The inner surface of the heated adaptive elements designed to generate additional local air turbulence and increase the heat exchange between the heating ring and air flow. On the other hand, the temperature of the heating rings dependent on their electric power and the position within the cylindrical tubular process heater. In simulating the two air flows varied from the value of 0.001m^3s^{-1} and 0.003m^3s^{-1}. Three combinations of adaptive heating elements analyzed: Combination A: 7x38W + 7x70W; Combination B: 7x70W 7x38W and Combination C: 14 x 54W. The results of these investigations presented below.

3.1. Fluid temperature

The research conducted for this work included three combinations (A, B, and C) of the heating elements with a total electrical power for each combination of 756W. The combination C is the solution that approximate corresponded with existing designs of the air process heater. The electric power of the each adaptive heated element is 54W while a total number of heaters is 14. As two comparative combinations used Combination A (7x38W + 7x70W), and Combination B (7x70W + 7x38W), which total power is equal 756 W. The increase of the air temperature for all three combinations and volumetric air flow rate of 0.001 m^3s^{-1}, shown in Fig. 3. The fastest increase of air temperature is for combination B, while much slower air heating has the adaptive process heaters with combinations B and C.

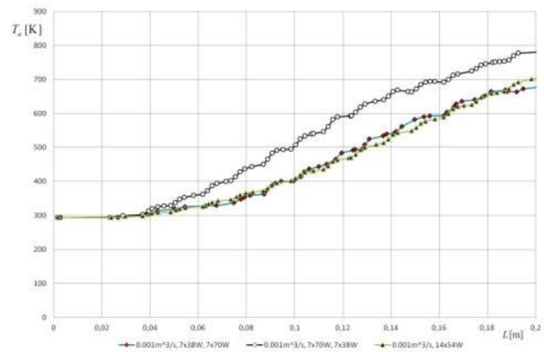

Figure 3: Comparison of air temperature (Combinations A, B, and C, $0.001 m^3 s^{-1}$)

The relationship between the output air temperature no significant changed for a volumetric air flow of $0.003 m^3 s^{-1}$, Fig. 4. And in this case, as in the previous two volumetric flows, the highest output air temperature achieved by using the combination B.

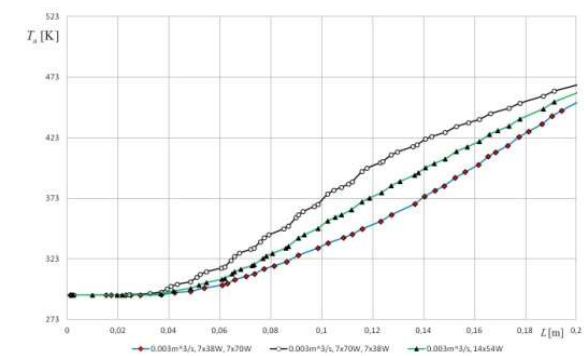

Figure 4: Comparison of air temperature (Combinations A, B, and C, $0.003 m^3 s^{-1}$)

3.2. Efficiency

The efficiency of the adaptive process heater defined as the ratio of the heat energy increase of the fluid in relation on the total installed electric power of the heating elements. The total number of the heating elements is 14, while the individual powers are 38W, 54W and 70W. The overall electric power installed in the first and other part of the process electric heater has a different value for the combination of A, B and C. For this reason, analyzed the energy efficiency of individual impact of the first and other half of process electric heaters, Figs.5 and 6.

The energy efficiency of the adaptive process heater in the case of the combinations A and B, determined by using the equation (1),

$$\eta_{A(B)} = \frac{\varrho_a V_a c_a (t_{a.out} - t_{a.in})_{A(B)}}{\sum_1^7 P_{el.I(II)} + \sum_8^{14} P_{el.II(I)}} \quad (1)$$

while the energy efficiency for the combination C of the adaptive process electric heater presented by the equations (2).

$$\eta_C = \frac{\varrho_a V_a c_a (t_{a.out} - t_{a.in})_C}{\sum_1^{14} P_{el.III}}. \qquad (2)$$

Where, c_a specific heat capacity of air, while $P_{el.I}$ =38 W, $P_{el.II}$ =70 W, and $P_{el.III}$ =54 W represent electric powers of the adaptive heating elements. The temperature increase of air flow for $(t_{a.out} - t_{a.in})_{A(B)}$ and $(t_{a.out} - t_{a.in})_C$ combination A, B, and C marked with and, respectively. The energy efficiency of the combinations A and C is approximate the same rate in the first part of the process heater, in the interval from 0 m to 0.1 m, Fig. 5. Combination B, 7x70W + 7x38W, along the entire length of the adaptive heater, has the highest energy efficiency.

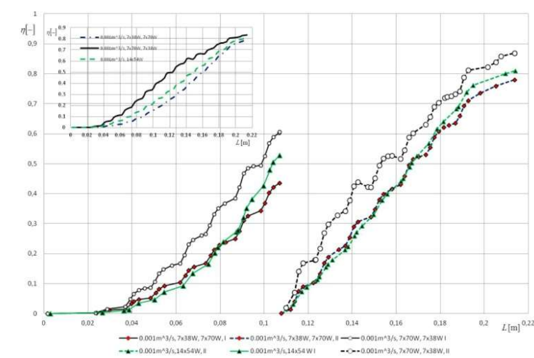

Figure: 5 Comparison of adaptive electric heater efficiency (Combinations A, B, and C, 0.001 m^3s^{-1})

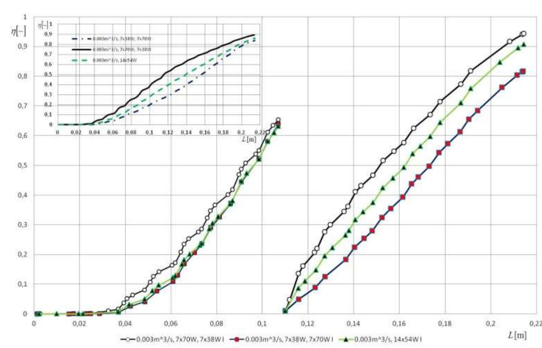

Figure: 6 Comparison of the adaptive electric heater efficiency (Combinations A, B, and C, 0.003 m^3s^{-1})

The ″wavy function″ of the energy efficiency $\eta(l)$ caused by the hydraulic air flow interaction with baffle sections of the adaptive heating elements. The energy efficiency $\eta(l)$ on the overall length of the process heater has the highest values for the combination B, in the interval from 0m to 0.2m, Fig.

6 on the top leftward. The ″wave function″ is not so noticeable to higher air volumetric flow rates of 0.003 m^3s^{-1}, Figs.6. The efficiency of the combination A and C has approximate the same values, in the interval from 0 m to 0.1m.

Table 1: The geometrical parameters of the adaptive process fluid heater

δ [m]	δ_1 [m]	d_1 [m]	d [m]	L[m]	D [m]
0.01	0.0002	0.01	0.012	0.186	0.023

4. CONCLUSIONS

The process electric heaters of the compressible fluids can produce in various shapes and sizes, and wide used in industry. The common characteristic of these heaters is the heating element in the form of electrical resistance wires, tapes or films. Since the air heated, all sections of the electric element are not in contact with air of the same temperature. For this reason, the efficiency of the heating element is different along the length of process heaters. On the other hand, any damage or melting of the heating wires, in one place, causing incorrect operation of the heating. In order eliminate the above shortcomings and increase the total efficiency of the process heating, proposed an innovative adaptive electric heater.
The results obtained for this investigation can represent through the following state:

- The adaptive heating elements can combine with each other by power, the dimensions and the position in relation on each other.
- The minimum value for the efficiency is for combination C (14x 54W) while the maximum efficiency is for combination B.

The limitations:

- In this paper neglected the hydraulic fluid losses during the passing through the adaptive process heater as local air turbulence.
- Furthermore, do not takes into account the heat loss due to the contact resistance and the state on the surface - adaptive heating element.

5. REFERENCES

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