MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION
ŚRODKOWO-POMORSKIE TOWARZYSTWO NAUKOWE OCHRONY ŚRODOWISKA
Annual Set The Environment Protection
Rocznik Ochrona Środowiska
Volume/Tom 19. Year/Rok 2017 ISSN 1506-218X 253-269

Studies on the Field Type Ground Heat Exchanger Coupled with the Compressor Heat Pump (Part 2)

Oktawia Dolna, Jarosław Mikielewicz
Institute of Fluid Flow Machinery of PASci

1. Introduction

Ground source heat pumps receive more and more attention and interest each day, because of their potential to reduce primary energy consumption. Consequently, lower amount of greenhouse gases is emitted to the atmosphere.

GSHPs are found to be highly efficient devices, which use renewable sources of energy for space heating and cooling. This technology exploits the phenomenon, which occurs naturally in our environment. Using the ground capacitance is regarded as a passive way of heating (cooling) of residual heat removal system. However, all benefits of GSHPs can be exploited only with the use of best management practices during installation, operation and decommissioning of these systems. It is really important to improve efficiency and quality of GSHPs, because use of the EESs can significantly reduce GGE. A.M. Omer (2011) states in his work that the GGE may by reduced even by 66 % compared to conventional energy supplying systems. Moreover, the GSHPs systems are meant to use 75 % less electricity than traditional ones, which work on fossil fuels (Omer, 2011). This technology is also very attractive from the economical point of view, because its operating cost is one-quarter of the conventional systems'.

Nowadays, researchers focus on ground heat exchangers mostly because the design heat-flow parameters of the working medium and the geometry of the heat exchanger have a huge influence on the heat pump work. However, the studies found in the literature do not include research on coupling the ground heat exchangers with the heat pumps. In order to fill in this gap, the present paper aims at presenting the analysis of the ground heat exchanger and the compressor heat pump cooperation. Therefore, a complex heat pump system analysis was planned to be carried out in this work. The heat pump system needs to be understood in terms of a compressor heat pump joined with a vertical ground heat exchanger. To sum up, the subject of the present work is a numerical analysis of the coaxial vertical ground heat exchanger coupled with a compressor heat pump cycle. For this purpose, the "0D"-"3D" level programming conjunction was applied. This, according to the literature, has not been done in practice until now.

The problem being discussed in the paper concerns the ground coupled heat pump quasi-steady intermittent work. Aiming to reach the goal, FGHE CFD analysis was carried out as the outlet FGHE parameters, influencing the CHP work, vary in time. Diurnal programmed FGHE work time was equal approximately from 4 to 6 hours. It was done intentionally to provide the ground's much time for its thermal regeneration. However, even though the FGHE did not work continuously and the ground's thermal regeneration occurred, the ground's temperature did not reach the initial value. On the basis of the CFD analysis the regeneration tempo was determined. These numerical researches have shown that heat pump should operate in a reversible mode so the ground could undergo a better thermal regeneration. Considering the fact that ground thermal efficiency decreases with time, it seems clear that ground cannot be thought of as inexhaustible. This is stated on the basis of the present work and the literature (Fidorów et al., 2015) and also on the basis of the technical companies practice (e.g. Viessmann).

The FGHE impact zone was also estimated. Mentioned impact zone must be understood in terms of the width of the ground layer surrounding FGHE, in which there occurs a temperature decrease being caused by FGHE operation.

2. Theoretical and numerical ground heat exchanger designing methods being used nowadays

In general, the CFD analysis gives the user the possibility of improving the innovative concepts of solving a wide range thermodynamic problems. Nevertheless, the numerical computations will never replace experiments and real measurements, it is still a source of a real and valuable data. The studies of the vertical ground heat exchangers described in the literature, focus mainly on the U-pipe ground heat exchanger. However, many researchers working on the U-type vertical ground heat exchangers do not couple U-pipes with a heat pump device, which is crucial in the overall heat pump system analysis. The work of Hanuszkiewicz-Drapała (2009) includes wider analysis of the ground heat exchanger, because the circulating pump flow characteristics have been taken into account.

The importance of the CFD analysis is confirmed also by the fact that the ground properties vary with depth. Moreover, the ground heat exchanger analysis becomes even more complex with the occurrence of ground water. In the light of these facts, it is obvious that numerical simulations may simplify solving the problem as numerical computations do not include any simplifications, which are being found in the analytical considerations. Moreover, the analytical calculations concerning the ground water occurrence, understood in terms of a flow heat source of a high capability to regenerate, may be burdened with a great inaccuracy.

2.1. Experimental analysis of the ground heat exchangers being carried out so far

As it has been mentioned earlier in the work, the subject of the research on the vertical ground heat exchangers are being mainly devoted to U-pipe analysis. There are very few works on the Field type Ground Heat Exchangers (FGHE). However, in the work of Yuehong Bi et al. (2002), there has been analysed a vertical double spiral coil ground heat exchanger. The numerical results, compared with the experimental data, are of a good accuracy. Yuehong Bi et al. have then also confirmed the necessity of carrying out the numerical analysis as it is a source of a valuable data. The FGHE case analysis, presented in this paper, has been carried out, because it is hard to find such an example in the literature. Suggestions of the designing process of the vertical ground heat exchangers mainly concern the U-pipe type (PORT PC, 2013). Moreover, the CFD analysis could be shortened while using the axisymmetric Field type heat exchanger model.

2.2. Computational domain description

The subject of the CFD analysis was the Field type ground heat exchanger. Its length was equal to 27.5 [m]. FGHE was hooked in a volume of the ground of one type. Two temperature boundary conditions were applied to the volume of the ground and are exposed in Fig. 1. First of them was a constant value and it was set on the upper ground's surface marked in green in Fig. 1. The other one was applied to the envelope of the computational domain as a temperature profile. Latter one consists of two linear functions. These functions may be arbitrarily changed so the implementation of different seasons may be executed. However, from the given depth, the atmospheric conditions do not influence the ground's temperature, indeed. As it is exposed in Fig. 1, the FGHE consists of two coaxial pipes. The external one had an oval bottom so the hydraulic resistance could had been reduced. Two pipes were made of different materials. The internal one was made of teflon as its thermal conductivity is low what was desired. The external one was made of polyethylene.

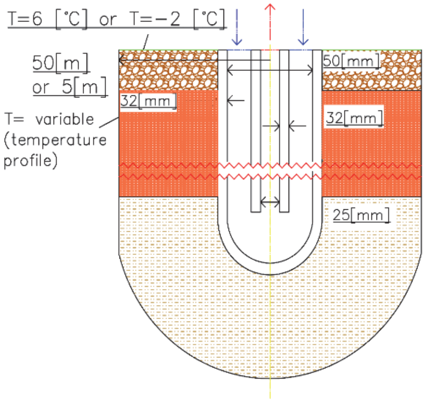

Fig. 1. Outline of the computational domain consisting of the FGHE and the ground (Dolna, 2016)

Rys. 1. Szkic domeny obliczeniowej, na którą składa się GWCF i grunt (Dolna, 2016)

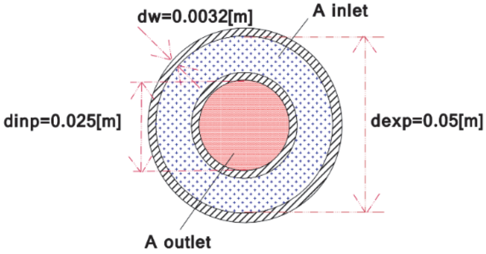

Fig. 2. Cross section of the FGHE, $\boldsymbol{\varepsilon}$ =0.41 (Dolna, 2016)
Rys. 2. Przekrój poprzeczny GWCF, $\boldsymbol{\varepsilon}$ =0.41 (Dolna, 2016)

The boundary conditions on the fluid side were as follows, the FGHE working medium inlet temperature, $t_{in} = 3[°\mathrm{C}]$, and inlet pressure, $p = 10\ [bar]$.

The FVM was used to discretise the computational domain. For the purpose of numerical calculations, the structural mesh was generated. Obviously, the mesh size varied according to the FGHE's length. The mesh influence was not discussed in the current paper however described problem is mesh independent as the proper analysis was carried out.

2.3. Results of the 0D-3D level programming coupling

This paragraph is devoted to the numerical model validation description and resulting single FGHE impact zone estimation. Further, the results of the FGHE-CHP conjunction are presented. Bearing on mind the ground's thermal depletion in time, its regeneration process was implemented and is discussed in this work. Worth mentioning is that the ground's regeneration has been implemented in the case of non-reversible CHP work. During the regeneration period, the FGHE did not work at all. Thermal ground's regeneration has been overlapping due to the temperature boundary condition applied to the envelope of the computational domain. Simultanously, the ground heat exchanger has not been working. Of course, the regeneration process would be more effective, from the heat transfer point of view, if the use of a reversible heat pump cycle would has been exploited. However, for the purpose of the current studies such system was not applied as it was meant to estimate the tempo of the ground's thermal regeneration without any heat injection into the ground.

3. Computational fluid dynamics results validation

Numerical investigation having been carried out concern LFGHE and SFGHE, from which the LFGHE was the reference model. It's length was equal 110 meters and **ε** was equal 0.41. Calculus presented in this paragraph is devoted to the reference FGHE. As the laboratory bench was not available, the numerical simulations were validated using theoretical algorithms, presented in the literature. Two separate analytical methods were applied. First one was a penetration theory, modified by J. Mikielewicz (Mikielewicz et al., 1996). The second one was Bose-Parker's algorithm (Zalewski, 2001).

In this paragraph, there are presented the results of the numerical simulations and theoretical considerations. As mentioned earlier in the text, there have been analysed two analytical methods, providing the possibility to determine the impact zone of a single vertical ground heat exchanger. As it can be seen further, a great convergence of the analytical and numerical results was obtained. This fact confirms the good quality of the CFD simulation results. First algorithm, having been used, was a so called penetration theory. It defines the width of the impact zone (Mikielewicz et al., 1996) (5):

$$\delta_{iz,M} = \sqrt{\pi \cdot a \cdot \tau} \tag{1}$$

where:

$\delta_{iz,M}$ – total width of the impact zone $[m]$,

a – the ground diffusivity $\left[\frac{m^2}{s}\right]$,

τ – characteristic time [s].

In order to calculate the width of the FGHE impact zone there was used the time of the heat exchanger work $\tau = 138600\ [s]$ (1). However, further in this paragraph another specific time is used when calculating the heat transfer coefficient on the soil side. Brief explanation is described below.

The second algorithm, used to validate the numerical simulations results, was the Bose-Parker method (Zalewski, 2001). Full calculus is available in the work (Dolna, 2016).

Primarily, there was calculated the unitary ground heat resistance for a single borehole, (2) (Zalewski, 2001), (Dolna, 2016):

$$R_{u\_gr} = \frac{I(x)}{2 \cdot \pi \cdot \lambda_{gr}} \tag{2}$$

where:

R_{u_gr} – unitary ground heat resistance $\left[\frac{m^2 \cdot K}{W}\right]$

$$I(x) = -0.5\, E_i(-x^2) \tag{3}$$

where the function E_i is defined as follows:

$$E_i(x) = \int_{-\infty}^{x} \frac{e^t}{t}\, dt \tag{4}$$

$$E_i(x) = \gamma + \frac{1}{2} \ln x^2 + \sum_{k=1}^{\infty} \frac{x^k}{k \cdot k!} \tag{5}$$

where:

$\gamma = 0.5772$ – Euler's constant

$$x = \frac{r}{2\sqrt{a_{gr} \cdot \tau_p}} \tag{6}$$

where:

$r = \frac{d_h}{2}$ distinctive dimension $[m]$,

where:

d_h – hydraulic diameter $[m]$.

Solving the integral-exponential function E_i, needed while using the Bose-Parker algorithm , was possible by dint of using author's code, presented in the appendix of the work (Dolna, 2016).

Considering equations (7) and (8), we get (9), on the basis of which, it is possible to derive eq.(11):

$$\dot{Q} = \frac{2\pi\lambda L}{ln\frac{r_2}{r_1}} \cdot \Delta T \tag{7}$$

$$\dot{Q} = \frac{2\pi\lambda L}{I(x)} \cdot \Delta T \tag{8}$$

Comparing the Bose-Parker algorithm results for the infinitive width with the finite thickness, it might be stated that :

$$\frac{2\pi\lambda L}{ln\frac{r_2}{r_1}} = \frac{2\pi\lambda L}{I(x)} \tag{9}$$

where:

$$r_2 = r_1 + \delta_{z,B-P} \tag{10}$$

$r_1[m]$ – external radius of the external pipe of the FGHE
$\delta_{z,B-P}[m]$ – width of the FGHE impact zone, determined using Bose-Parker algorithm.

$$\delta_{z,B-P} = r_1(e^{I(x)} - 1) \tag{11}$$

Two algorithms, presented above, give the following results (18), (19), respectively. Obviously, these values, (12), (13), have been determined with the use of exactly the same parameters as in the numerical simulations (14).

However, results (18) and (19) differ from each other. This is being caused mainly by the differences of the methodology of two algorithms having been used. The penetration theory provides only estimation of the magnitude of the searched values. The Bose-Parker algorithm is more precise as it includes characteristic geometry parameters of the FGHE such as its length and hydraulic diameter. That is why a great convergence of the CFD (13) and Bose-Parker algorithm (14) results was obtained.

$$\delta_{\ z,M-K} = 0.77\ [m] \tag{12}$$

$$\delta_{\ z,B-P} = 1.19\ [m] \tag{13}$$

$$\delta_{\ CFD} = 1.22\ [m] \tag{14}$$

As mentioned earlier in this paragraph, the penetration theory was also used to estimate the value of the ground heat transfer coefficient, $\alpha_{gr}\left[\frac{W}{m^2K}\right]$ (21). In this particular case, the time $\tau_{pf} = 440\ [s]$ was the time of a particle flow from the top to the bottom of the LFGHE. As a result, the boundary layer thickness was obtained, $\delta_{bl} = 4 \cdot 10^{-4}\ [m]$, which allows to calculate the ground heat transfer coefficient, α_{gr} :

$$\alpha_{gr} = \frac{\lambda_{gr}}{\delta_{bl}} \left[\frac{W}{m^2 K}\right] \tag{21}$$

where:

$\lambda_{gr} = 2.18 \left[\frac{W}{mK}\right]$

$\alpha_{gr} = 54.5 \left[\frac{W}{m^2 K}\right]$.

The α_{gr} value is consistent with data presented by Zalewski (2001).

4. Intermittent quasi-steady GCHP work analysis

As it is commonly known, the GCHP compressor of a well-designed system should operate in the annual time range varying from 1800 to 2400 hours. Unfortunately, even though the heat pump systems have a long history, they are still being over- or undersized. This happens if the designing process does not overlap in a proper way. Nevertheless, this work concerns the ground's regeneration process and instability of the FGHE heat flux value during the intermittent GCHP work. The GCHP working medium having been used for the purpose of the current work was R600a. This fluid is thought to be one from equivalents for R134a (Bohdal et al., 2012). Bearing on mind this problem, the periodic GCHP system work was programmed. For the purpose of the FGHE – CHP conjunction, the 0D-3D level programming was applied. Regarding the fact that the FGHE diurnal work was equal 4 to 6 hours, interchangeably, much time for the ground's thermal regeneration was included. Even though, the soil has not been extremely exploited by the FGHE, the ground' s thermal regeneration proceeded in a long term, what is described further in this article.

The graph exposed in Fig. 3 shows the results of the FGHE intermittent work. The FGHE length was 27.5 [m]. The mass flow rate of the FGHE working fluid was equal 1.1 $\left[\frac{kg}{s}\right]$. As the analysis which has been carried out is mostly of a qualitative character, the FGHE working fluid was chosen from the commercial computational tool fluid database. The possible to use working medium was 100% ethylene glycol. However, in the practice the (30-60)% ethylene glycol brines are being used.

Application of the 100% ethylene glycol consequently resulted in higher hydraulic resistance, however for the purpose of the herby presented analysis it did not really matter that much as the analysis is mostly of a qualitative than quantitative character.

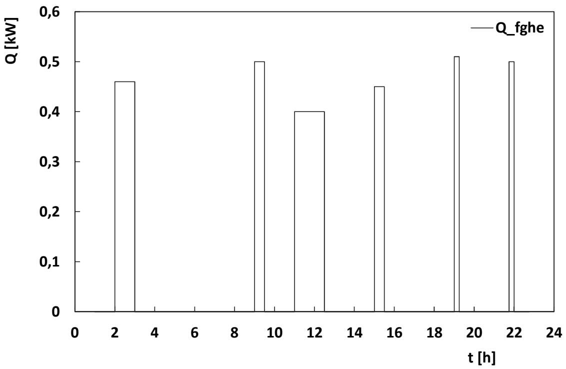

Fig. 3. Diurnal heat flux variation during the intermittent FGHE work (Dolna, 2016)
Rys. 3. Dobowe wahania wartości strumienia ciepła pozyskiwanego z gruntu za pośrednictwem GWCF podczas pracy przerywanej (Dolna, 2016)

As the heat flux received via FGHE varied during the work time, the GCHP COP also changed, consequently, what can be observed in Fig. 4.

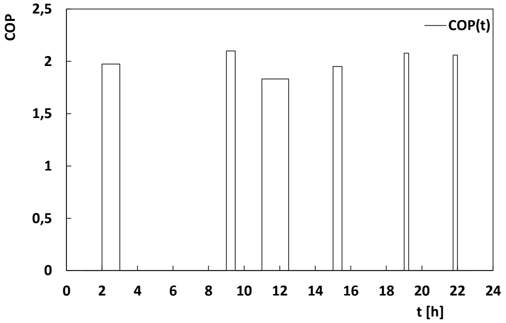

Fig. 4. GCHP COP value change during the intermittent work time (Dolna, 2016)
Rys. 4. Zależność wartości COP GCHP od czasu podczas pracy przerywanej (Dolna, 2016)

As it is presented in Fig. 3 and Fig. 4, it can be stated that even though the ground has had relatively much time for its thermal regeneration, the heat flux transferred from the borehole via FGHE was not constant during the intermittent work time period. This fact should be considered and taken into account at designing level. In the case, of which the results are discussed in the paper, the ground's regeneration has been executed through cutting off the FGHE working medium flow. The temperature boundary conditions, having been applied to the envelope of a studied domain, have forced the ground's temperature to increase. This phenomenon of thermal regeneration has taken much time. This fact is importing, because of the following assumption. The GCHP systems should work in the reversible mode. Applying this solution would extend the life cycle of the ground working as a low heat source. In other case the ground's degradation would overcome relatively fast and the ground would not regenerate in a proper way. It means that the ground could not be called a renewable source of energy as the ground's thermal efficiency would decrease significantly.

5. Influence of FGHE on the surrounding ground

This paragraph concerns the effect of FGHE operation in the soil, understood in terms of the ground's temperature decrease. Figure presented below (Fig. 5) exposes the work time and the depth dependent temperature distribution in LFGHE surroundings . On the *x* coordinate the distance from FGHE external wall is given. In the centre of the coordinate origin FGHE is placed. Fig. 5 presents the soil's temperature layout, starting from the FGHE external pipe surface. Data, visualised through this characteristics, was collected on the way of continuous FGHE work lasting 39 hours. Numerical simulations had run in transient mode. For each work hour and three different depths (10 [m], 30 [m], 110 [m]), the temperature profile was obtained.

From Fig. 5 it can be observed that the FGHE impact zone is of a cone shape and it is wider at lower depths, i.e. yellow and pink line in Fig. 5. It can be noticed that deeper FGHE reaches, the thinner FGHE impact zone is.

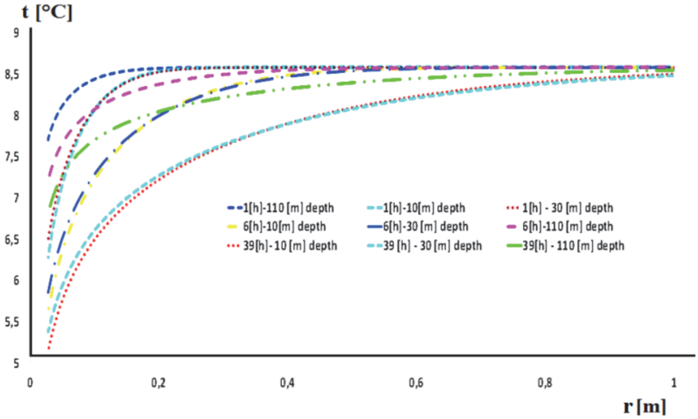

Fig. 5. Temperature distribution at different depths in the ground after 1[h], 6[h], 39[h] of FGHE continuous work (Dolna, 2016)
Rys. 5. Rozkład temperatury w gruncie na różnych głębokościach po 1[h], 6[h], 39[h] godzinach pracy GWCF (Dolna, 2016)

In the following graph, Fig. 6, results of the intermittent SFGHE work are displayed. During the intermittent SFGHE work, SFGHE operated in the time range described the previous paragraph of present paper. All lines, exposed in Fig. 6, correspond to stages of the ground regeneration which coincide with SFGHE no operation period during the intermittent SFGHE week work. The blue line is identical to the first regeneration period during the first day of work. As the ground regeneration occurred interchangeably with the SFGHE work the ground's temperature varied in an unpredictable way. The red line corresponds to the last regeneration period during the seventh work day. Other lines show how did the soil's temperature changed during following regeneration periods during the first work day. From Fig. 6 it can be seen that even though the ground had relatively much time for its thermal regeneration, this process had not proceed with a satisfactory efficiency as the soil's temperature decrease was equal $\Delta T = 1.4[°\mathrm{C}]$.

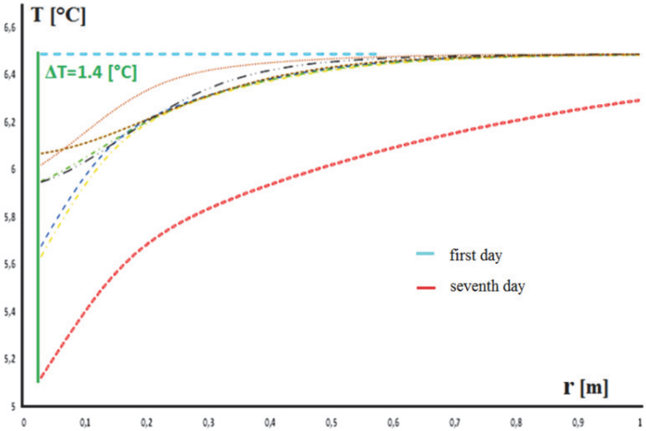

Fig. 6. Ground's thermal degradation (Dolna, 2016)
Rys. 6. Degradacja termiczna gruntu (Dolna, 2016)

Figures attached below(Fig. 7, Fig. 8, Fig. 9) present the CFD analysis results. The subject of investigation was SFGHE of ε =0.41. Its work was continuous and has been lasting for 446 hours. After that time, the ground's temperature decreased significantly (Fig. 7). During its work, FGHE mass flow rate was equal 1.1 $\left[\frac{kg}{s}\right]$. Then, the ground's thermal regeneration was implemented, for the purpose of which, FGHE working medium flow was stopped. The ground's temperature increased as well as the temperature profile, having been set as a boundary condition, forced it to. After 1060 hours of a continuous regeneration, the ground's temperature distribution was like it is exposed in Fig. 8. The ground's temperature reached its initial state value after 4131 hours of uninterrupted regeneration Fig. 9.

Temperature distribution exposed in Fig. 9 is forced by the temperature profile applied to the envelope of a studied computational domain. This isothermal surfaces layout corresponds to the initial state temperature distribution.

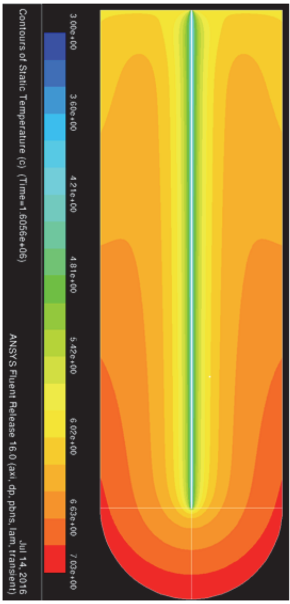

Fig. 7.

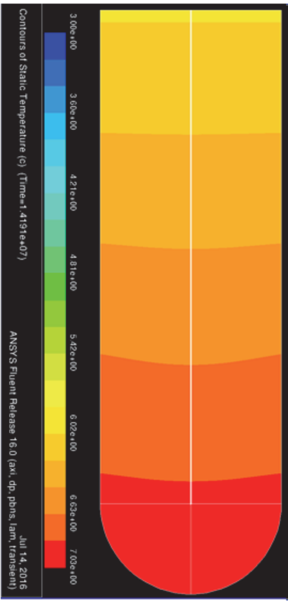

Fig. 8.

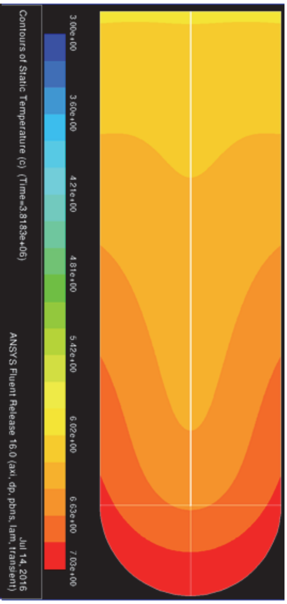

Fig. 9.

Fig. 7. Isothermal surfaces layout in the ground after 446 hours of SFGHE continuous work (Dolna, 2016)
Rys. 7. Rozkład powierzchni izotermicznych w gruncie po 446 godzinach ciągłej prac 27.5 [m] GWCF (Dolna, 2016)

Fig. 8. Ground's temperature increase after 1060 hours of thermal regeneration (Dolna, 2016)
Rys. 8. Wzrost temperatury gruntu po 1060 godzinnej regeneracji termicznej (Dolna, 2016)

Fig. 9. Isothermal surfaces layout after 4131 hours of the ground's thermal regeneration (Dolna, 2016)
Rys. 9. Rozkład powierzchni izotermicznych w gruncie po 4131 godzinach nieprzerwanej regeneracji termicznej gruntu (Dolna, 2016)

6. Summary

The numerical simulations results of the intermittent and continuous FGHE work, presented in the paper, have shown, how does the FGHE impact zone vary with the FGHE work time and its geometry. The results confirm the thesis about the low heat source's (the ground) thermal efficiency depletion in time. Despite the fact that the FGHE work was of the intermittent character and the low heat source could regenerate, the surrounding ground did not reach the initial temperature value during the week work. On the basis of the CFD simulations having been carried out, an important assumption is stated. The ground's thermal efficiency decreases significant in time. According to this, the ground remains a renewable source of energy only if the condition of a well ground heat exchange system design is fulfilled. Moreover, the GCHP systems should operate in a reversible mode to improve the ground's thermal regeneration.

The results presented in the paper have shown that the quasi-steady FGHE work character should be taken into account at the GCHP system designing level.

Nomenclature

GGE – greenhouse gases emission,
FGHE – Field type ground heat exchanger,
CFD – computational fluid dynamics,
GWCF – gruntowy wymiennik ciepła typu Fielda,
GSHP – ground-source heat pumps,
GWHP – ground-water heat pump,
SWHP – surface-water heat pump,
GCHP – ground-coupled heat pump,
EESs – earth-energy systems,
LFGHE – long FGHE (110 [m]),
SFGHE – short FGHE (27.5 [m]),
HP – heat pump,
CHP – compressor heat pump,
COP – coefficient of performance,
0D – zero-dimensional,
3D – three-dimensional.

Greek symbols

$\varepsilon = \frac{A_{outlet}}{A_{inlet}}$ – epsilon – inlet/outlet surface ratio,
$\lambda \left[\frac{W}{m\,K}\right]$ – thermal conductivity,
$\varrho \left[\frac{kg}{m^3}\right]$ – density,
γ – Euler's constant.

Subscripts

gr – ground,
pf – particle flow,
bl – boundary layer,
iz – impact zone,
M – Mikielewicz,
$B\text{-}P$ – Bose-Parker,
h – hydraulic.

References

Bohdal, T., Charun, H. (2012). *Zasady transportu ciepła cz. 1*. Koszalin: Politechnika Koszalińska.

Bohdal, T., Charun, H., Sikora, M. (2015). Wybrane aspekty prawno-techniczne i ekologiczne stosowania sprężarkowych pomp ciepła. *Rocznik Ochrona Środowiska*, *17*, 461–484.

Dolna, O. (2016). *Influence of the ground heat exchanger design heat – flow parameters on the heat pump efficiency.* Institute of Fluid Flow Machinery, PhD dissertation.

Fidorów, N., Szulgowska-Zgrzywa, M. (2015). Temperature monitoring in the vertical borehole of the heat pump, *Rynek Instalacyjny*, *4*.

Hanuszkiewicz-Drapała, M. (2009). Modelowanie zjawisk cieplnych w gruntowych wymiennikach ciepła pomp grzejnych z uwzględnieniem oporów przepływu czynnika pośredniczącego. *Modelowanie Inżynierskie*, *38*, 57-68.

Mikielewicz, J., Grochal, B., Polesek-Karczewska, S., Gumkowski, S., Mikielewicz, D. (1996). *Heat Exchange*. Gdańsk: Institute of Fluid Flow Machinery PASci (in Polish).

Omer, A.M. (2008). Ground-source heat pumps systems and applications. *Renewable and Sustainable Energy Reviews*, *12*, 344-371.

Polska norma: PN-82-/B-02403 – Ogrzewnictwo. Temperatury obliczeniowe zewnętrzne.

PORT PC. (2013).Wytyczne projektowania, wykonania i odbioru instalacji z pompami ciepła, Cz. 1, Dolne źródła do pomp ciepła.

Xiao, C., Xiaoli, H., (2015). Exergy Analysis of a Ground-Coupled Heat Pump Heating Systems with Different Terminals. *Entropy, 17*, 2328-2340.

Yuehong, B., Lingen, C., Chin, W., (2002). Ground heat exchanger temperature distribution analysis and experimental verification. *Applied Thermal Engineering*, *22*, 183-189.

Zalewski, W. (2001). *Compressor, Sorption and Thermoelectric Heat Pumps.* IPPU MASTA (in Polish).

Badania gruntowego wymiennika ciepła typu Field'a współpracującego ze sprężarkową pompą ciepła (część 2)

Abstract

This work concerns the numerical research on the ground coupled compressor heat pump quasi-steady intermittent work. To reach the goal 0D-3D level programming coupling was applied. The work contains also the analysis of the influence of a single Field type vertical ground heat exchanger on the surrounding ground. Numerical model was validated using Bose-Parker's algorithm and penetration theory modified by J. Mikielewicz. In order to determine the ground's ability to thermal regeneration, CFD simulations of the Field type ground heat exchanger were carried out.

Streszczenie

Niniejsza praca poświęcona została badaniom numerycznym quasi-stacjonarnej przerywanej pracy gruntowej sprężarkowej pompy ciepła. By osiągnąć zamierzony cel sprzęgnięto programowanie na poziomie 0D i 3D. W pracy zawarto również analizę szerokości strefy wpływu pojedynczego GWCF. Powyższe należy rozumieć jako obszar termicznego oddziaływania na grunt pionowego współosiowego gruntowego wymiennika ciepła. Walidacja modelu numerycznego została przeprowadzona w oparciu o algorytm Bosego-Parkera oraz teorię penetracji zmodyfikowaną przez J. Mikielewicza. Chcąc określić zdolność gruntu do termicznej regeneracji przeprowadzono symulacje CFD, których wyniki załączono w niniejszej pracy.

Słowa kluczowe:
Wymiennik gruntowy typu Field'a, 0D-3D, CFD, sprężarkowa pompa ciepła

Key words:
Field type ground heat exchnager, 0D-3D, CFD, compressor heat pump