別紙第１号様式　　　　　　　　　　　　　No.1

博　士　論　文　の　要　旨

専攻名　システム創成科学専攻
氏名（本籍）Teguh Hady Ariwibowo (Indonesia) 印

博士論文題名
（外国語の場合は，和訳を付記する。）

Influence of Discrete Double Inclined Ribs on Performance of Ground Heat Exchanger for Ground Source Heat Pump
（地中熱ヒートポンプ用地中熱交換器の性能に及ぼす離散二重傾斜リブの影響）

要旨（２，０００字程度にまとめること。）

In this study, three-dimensional low flowrate heat transfer and flow in Slinky-coil Ground Source Heat Exchanger (GHE) with the addition of Discrete Double Inclined Ribs (DDIR) to several geometry configurations. This study is divided into two parts, namely the analysis of the flow of phenomena in the pipe (ideal conditions, no heat loss and steady-state) and the analysis of phenomena in the flow of water in the pipe and heat transfer on the ground (transient). The continuity, momentum, energy, turbulence equation is solved by a commercial software Computational Fluid Dynamics ANSYS Fluent 17.2.

In the first analysis, the study aimed to look at the potential use of DDIR in several geometry configurations, namely ribs height, axial ribs pitch, angle of ribs, and curvature coil.

Two pairs of DDIR-coil on one perimeter only produce one pair of vortex compared to DDIR-straight, which is capable of producing two pairs of the vortex. However, DDIR-coil can distort secondary flow and strengthen turbulent flow. Heat Flux on the DDIR-coil wall experiences significant fluctuations compared to DDIR-coil. In general, the heat flux in the plain coil becomes smaller with increasing axial length coil. This phenomenon is due to the difference between Bulk and wall temperature. The bulk temperature becomes closer to the set point than that of plain-coil.

The effect of increasing Ground Source Heat Pump (GSHP) performance due to GHE modification was evaluated using COP Improvement Factor, which is calculated based on energy loss due to pressure drop and energy saving due to heat transfer enhancement. COP Improvement Factor has increased along with increasing ribs height. However, the COP improvement factor decreases with increasing

博　士　論　文　の　要　旨

専攻名　システム創成科学専攻
氏名 Teguh Hady Ariwibowo

flow rate.

Based on the DDIR-coil flow structure, the longitudinal vortex is clearly visible around the ribs and has almost the same strength as DDIR-straight. The combination of secondary flow from coil and flow generated causes the path of water particles to be longer than plain-coil. This flow increases better thermal mixing than plain-coil.

DDIR-coil performance is always lower than DDIR-straight with the same axial tube length. This behavior is because in DDIR-straight flow is only dominated by primary and secondary flow due to curvature coil, while in DDIR-coil water flow is a combination of primary, secondary flow from the coil and flow generated by ribs. These three streams interfere with each other. COP improvement factor increases with decrease in axial pitch between ribs. DDIR has the highest COP improvement factor at an angle of 20 ° ribs. Whereas the 2.66 /m curvature coil has the highest COP Improvement factors among the other curvature coils.

The second analysis looks at the thermal behavior of GHE and its impact on the soil. In this research, DDIR-coil performance was only superior during 149 minutes of operation compared to turbulent flow plain-coil. Whereas the DDIR-coil laminar flow has higher performance than plain-coil at all operating times.

GHE operation is carried out in continuous and 120-minute intermittent mode variations. At the end of the operation, intermittent operation showed a heat transfer rate of 17.3% greater than that of continuous operation. The intermittent mode also gives time to the ground for thermal recovery.

Three pipe materials, namely copper, composite, and HDPE, is tested to determine the effect on coil performance. Copper has the best thermal performance compared to the other two materials, especially in the first 60 minutes of operation. However, the remaining operating time of the copper coil has almost the same performance as other materials. It was found that

博　士　論　文　の　要　旨

専攻名　システム創成科学専攻
氏名 Teguh Hady Ariwibowo

the use of pipe material did not significantly influence the performance of DDIR-coil and plain-coil.

Based on observing the flow structure in the pipe, DDIR-coil should have a higher performance than plain-coil. Sand, Sandy clay and clay are examined to see the influence of its thermal conductivity on the GHE performance. It is found that ground conductivity is more powerful than convection DDIR-coil regarding heat transfer rate of GHE.