Preliminary study of inert gas flow analysis on thermal systems with natural convection conditions

R Anshari *, Mairizwan, A Asrizal, A Akmam

Physics Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, Indonesia

*rioanshari@fmipa.unp.ac.id

Abstract. Coolant circulation in a thermal system can pass through two circulation pathways, namely natural circulation and forced circulation. Both types of circulation each have advantages and disadvantages. Forced circulation requires special equipment to be able to supply pressure at the beginning of the coolant circulation. If this special equipment fails to function, it can lead to failure of the cooling process and can be fatal to the system that is run. As with natural circulation, this circulation does not require special equipment to drain the coolant. Coolant flow naturally by utilizing different densities of coolant. For systems that work where the axial flow is in the vertical direction, there is an influence of the coolant gravity which affects the coolant flow. This study aims to analyze how the inert gas flow patterns that occur in a thermal system that applies natural circulation, in this study the focus of the study is on the coolant with the gas phase. This research is a type of experimental research. The analysis was conducted using descriptive and numerical analysis methods. The results of the analysis have been obtained, then applied to a thermal system that applies natural convection to the gas flow. The results of the analysis and application of this study are expected to provide meaningful input for the development of coolants in thermal systems and specifically in cooling systems for gas-cooled reactors. The results of preliminary studies that have been carried out have obtained basic benchmarks that can be used as guidelines for analyzing the physical conditions of the inert gas flow in the heat system by setting some standard conditions found in thermal systems that are generally used today.

1. Introduction

The occurrence of Japan's Fukushima nuclear accident case in 2011 has become a valuable lesson especially researchers engaged in the field of nuclear energy. The failure of the cooling pump at the Fukushima reactor facilities is one of the causes of the explosion at this reactor facilities. Learning from this case, some research communities have begun to develop a cooling system that does not depend on pump work or also known as a passive cooling system [1].

Cooling circulation in a system that works with the mechanism of heat engine can pass through two circulation pathways, namely natural circulation and forced circulation. Both types of circulation each have advantages and disadvantages. Forced circulation requires special equipment to be able to supply pressure at the beginning of the cooling circulation. If this special equipment fails to function, it can result in the failure of the cooling process and can be fatal to the system it supports. As with natural circulation, this circulation does not require special equipment to drain the cooler. Coolers flow naturally
by utilizing different densities of coolers. For systems that work where the axial flow is in the vertical direction, there is an influence of the cooling gravity which affects the cooling flow. The application of this natural circulation system is appropriate for reactors that use a gas-type cooler because the type of heat flow in the form of normal convection will make the gas naturally move upward without requiring a pump to move it. In addition, the heat condition of the reactor core also has a positive effect on the vertical gas flow rate. The use of inert gas is also a part that is considered to minimize the contamination of nuclear reactions to be exposed to the outside environment. Some related studies are used as a reference in working on simulations, including research by Haskins et al [2], Franken et al [3] and Oztop et al [4].

In addition to gas accuracy for the application of natural circulation, gas reactors can also be used for hydrogen production. As the design of transportation systems in the future where there are opportunities for the use of hydrogen-fueled vehicles, the application of this type of reactor also has a good opportunity to support the fulfilment of energy and materials in the future.

2. Research Methods
This research is a numerical calculation using a computer and carried out in the Computational Labor Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang. The research method used is a quantitative method of numerical calculation using numerical analysis models to assess the magnitude of the research variables in the case conditions observed. The observed variables are temperature variation, temperature distribution and pressure drop with axial orientation. Inert gas flow in natural convection conditions.

![Research Scheme](image)
The design of the research carried out is to do numerical calculations of temperature variations, temperature distribution and pressure drop with axial references on the regular inert gas flow channel then find the best conditions that produce the appropriate variables to be used as a reference in its application in gas-cooled reactors without the use of pumps coolant. For flow configuration, the authors use a gas reactor channel whose configuration is adapted from Waltar [5]. Figure 1 shows the research scheme that has been implemented.

3. Result and Discussion

3.1. System Configuration

The following is the configuration of the channel system used in the simulation which has been tested

| Parameters               | Unit | Value |
|-------------------------|------|-------|
| Inside diameter of shell| mm   | 3,900 |
| Tube outside diameter   | mm   | 29    |
| Effective length of tube| mm   | 4,000 |
| Number of tube          |      | 790   |
| Tube pitch              | mm   | 75    |
| Center region area      | %    | 2.5   |
| Flow channel number     |      | 3     |

Of the several channel systems tested, the configuration of the channel system as shown in table 1 above is a recommended configuration because it produces variables that match the purpose of the study. The variables examined in this study will be presented at the point after this.

3.2. Temperature Variation

Temperature Variation is a pattern / description of how the temperature range of the coolant in this case is gas along the channel flow. For specifications used, the following temperature variation results have been obtained:

![Temperature Variation](image1)

Figure 2. Temperature Variation of the channel system

From the results of the channel numerical simulation, we can get the form of temperature variation as seen in Figure 2 above. It can be seen that the temperature variation on the channel in axial orientation shows conditions where there is a stable variation from the core to the edges. This pattern is the expected form of temperature variation to be achieved from this study. This pattern is obtained by the channel configuration form following the basic configuration described in the previous section.

3.3. Temperature Distribution

Temperature Distribution is a pattern / picture of how the temperature distribution of the coolant along the canal. For the specifications used, the following temperature distribution results have been obtained:

![Temperature Distribution](image2)
From the results of numerical simulations carried out in research activities, obtained the shape of the temperature distribution meets the shape of the pattern diahat carved in Figure 3 above. Figure 8 shows the heat carried by the coolant evenly distributed to the coolant in axial orientation. Heat transfers from the canal and heat source are distributed to the center of the canal and almost homogeneous distribution to the edges. This form is obtained by applying the channel system configuration that has been described in the previous section. The configuration of the channel system is also recommended considering the temperature distribution form which is quite homogeneous.

3.4. Pressure Drop
Pressure Drop is a pattern / illustration of how the pressure drop from coolant flow along the canal. For the specifications used, the following pressure drop results have been obtained:

From the simulation results by applying the channel configuration that has been described previously, the resulting Pressure Drop shape is generated as shown in Figure 4 above. From Figure 4 you can see that the Pressure Drop from the coolant is quite homogeneous and gradually decreases from the middle to the edges which are directly in contact with the canal wall. The shape of this pattern is quite ideal to be applied to heat engines that require a cooling system especially those that use gas as a coolant.

4. Conclusion
The simulation of a cooling system that applies passive cooling with natural convection has been successfully carried out. A proper channel configuration is obtained to fully support natural convection. The results of this study will be continued for application to the reactor cooling system.

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