TEMPERATURE MAPPING OF TRIGA 2000 REACTORS AT 500 kW POWER WITH 105 CONFIGURATIONS OF PRE-RESHUFFLING AND POST-RESUFFLING FUEL

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Abstract *The continuity of operation of the TRIGA 2000 reactor is thermohydraulically determined by the temperature of the fuel and the temperature of the primary cooling water in the reactor core. Currently, the operation of the TRIGA 2000 reactor at a power of 500 kW using a fuel 105 configuration in the core has caused boiling and the formation of bubbles in the reactor core, thereby reducing neutron moderation. The core of reactor is unable to achieve more power. One of the efforts that can be made to reduce the core temperature of the TRIGA 2000 reactor is by reshuffling the fuel inside the core, including using 105 fuels but shifting the position of the fuel to a different ring. In this research, thermohydraulic analysis has been carried out using the FLUENT program package for the configuration of 105 fuels in the pre-reshuffling and post-reshuffling core. Based on the results of the study, it is known that at 500 kW of power with a pre-reshuffling fuel configuration, there are positions for sub-cooled boiling in B3, B4, B5, B6, D4, D6, D8, D10, and D12. The hottest channel is at B5 with a maximum fuel cladding surface temperature of 126.41 °C, and a cooling water saturation temperature in the core of 112.4 °C. Meanwhile, for the post-reshuffling fuel configuration there is no position for sub-cold boiling in the core, where the maximum temperature is at B2 with the maximum fuel cladding surface temperature of 93.55 °C. Thus, it is concluded that the TRIGA 2000 reactor with a configurations of 105 post-reshuffling fuel can be operated at of 500 kW without boiling or at least not occurring sub-cold boiling.*

INTRODUCTION

The emergence of bubbles in the Triga 2000 reactor with a cooling system of the Natural Convention Core is very easy to observe because of the direction of the cooling flow from the core to the surface of the reactor tank. This bubble visualization is very useful in investigating the growth of the number of bubbles that occur in the reactor core.

The phenomenon of the emergence of bubbles in the 2000 Triga reactor is possible because there is capitation in the primary pump (1), the high heat on the core due to the inability of heat transfer by the primary cooler and secondary cooler (2), the measured power is lower than the actual power, the phenomenon of radiolysis on the core reactor (3-5), and corrosion growth (6).

The growth of the number of bubbles on the Triga 2000 reactor core needs to be observed, because bubbles will cause the reactor power to be unstable (7). Increasing the number of bubbles due to the occurrence of boiling in the core will reduce the process of neutron moderation so that the reactor power decreases. When the reactor power decreases, the boiling is reduced and the number of bubbles formed is also reduced, so that the neutron moderation process increases again and the reactor power rises. Conditions down and the rising power of this reactor will continue to occur continuously, and the reactor is unable to achieve higher power.

The occurrence of boiling in the reactor core because the fuel surface temperature on the reactor core becomes higher than the temperature of the cooling water saturation in the core. This is due to limited amount of fuel use, high fuel burn-up values (close to 50%), and fuel configuration is no longer optimum. The fuel configuration in the core is carried out by calculating the amount of fuel available, fuel burn-ups, and fuel life.

At present, the operation of the 2000 Triga reactor at 500 kW power has begun to form bubbles as a sign of boiling (boiling), or at least the sub-cooled boiling has occurred in the core. Given the conditions that are happening, in order to overcome the boiling, it is necessary to do reshuffling by first determining the pattern of new fuel configuration in the core. To determine the optimum configuration pattern of the material in the core, it is necessary to evaluate the amount of fuel used, burn-up fuel and fuel life (8-10).

In this study, the Triga 2000 reactor core is thermohydraulic analysis using a fluent program package to map the reactor core temperature at 500 kW power with a configuration of 105 fuel in the reactor core both before reshuffling or after reshuffling so that the positions can be known the core has occurred or at least sub-cooled boiling.

Triga 2000 reactor core

The Triga 2000 reactor core has 121 grids to place fuel and other facilities in the core. At present, the Triga 2000 reactor core uses a configuration of 105 power generation that occupies 105 grids, consisting of 97 fuel, 3 fuel follower control rod-ffcr, 5 instrumented fuel elements. In addition, 1 grid was placed in Neutron Source-NS, 2 grids were placed in control stems without fuel-CRWF, 4 grids were placed in irradiation-IF facilities, 4 grids were placed in graphite, and 5 grids were emptied (10), as shown in Figure 1.

The reshuffling form is to continue to use the 105 fuel configuration but shifts the position of the fuel and other core facilities to a different ring, as shown in Figure 2.

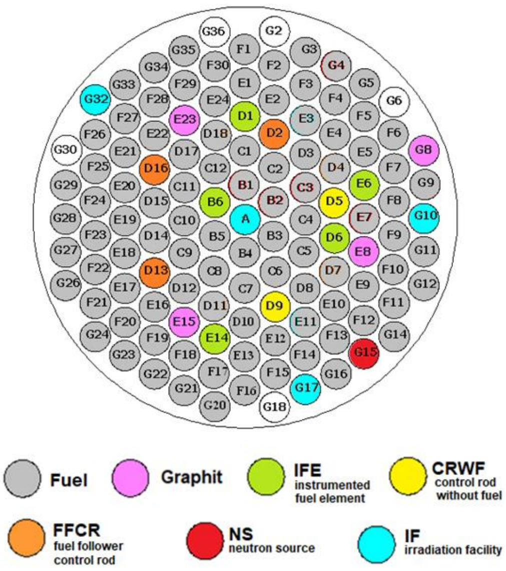


Figure 1. Configuration of 105 fuels pre-reshuffling.

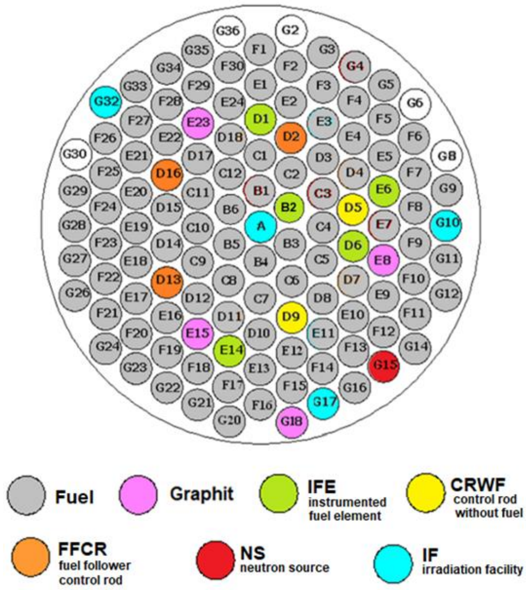


Figure 2. Configuration of 105 fuels post-reshuffling.

FLUENT Software

Fluent is one type of CFD (Computational of Fluid Dynamics) program that uses the volume method up to. Fluent provides complete mesh flexibility, so that it can solve the case of fluid flow with unstructured mesh even in a relatively easy way. The type of mesh supported by fluent is the 2D triangular-quadrilateral type, 3D tetrahedral-hexahedralpyramid-wedge, and mixed mesh (hybrid). Fluent also provides facilities to refine or enlarge existing mesh (11, 12).

Numerical modeling in this study was carried out using fluent devices version 6.2.16. The numerical simulation of the volume of the set that has been made with the gambling program is carried out for a steady condition. In the numerical modeling, several assumptions are needed, including the conduction of heat transfer on the inner and outer walls, and radiation heat transfer from the inner and outer walls in the model is ignored.

The numerical modeling is defined by the models using pressure-based because the flowing flow is incompressible at low speed. The energy equation must be activated in order to model the process of heat transfer that occurs in the system. The type of fluid used is water (H_2O). The physical properties of water such as density, viscosity, thermal conductivity, and type of heat are modeled as a temperature function.

The effect of gravitational acceleration is also included in the system with a value of 9.8 m/s. Gauge pressure = 0 pa.

Setting the boundary condition on the volume of the set is done by entering the quantitative value of the parameters related to the Boundary type, including the large heat flux on the fuel surface. Heat configuration on the surface of the fuel with a constant heat flux.

Data output results of iteration/calculations carried out by the Fluent program, including in the form of a fuel surface temperature distribution and cooling water temperature.

METHODOLOGY

There are 17 stages carried out in achieving the objectives of this study, namely:

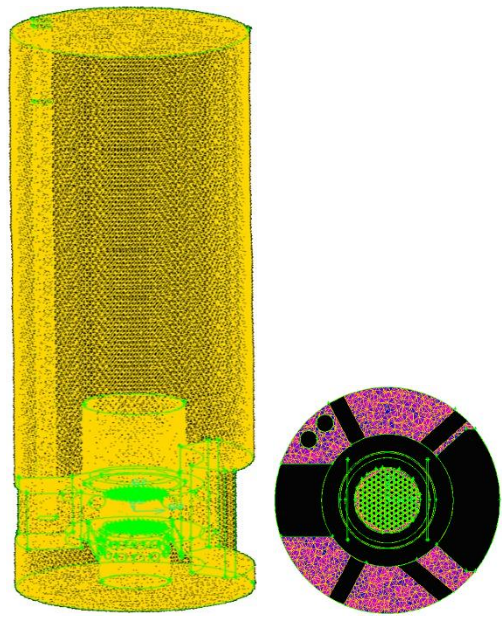
1. Creating the Geometry Model of the Triga 2000 and Mesh reactor in the Triga 2000 reactor model uses a gamble program package.
2. Choosing the right solver for the 3D model.
3. Import mesh/grid model,
4. Conduct an examination of the mesh,
5. Select Solver Formulation,
6. Select the basic equation that will be used in analysis, for example: laminar, turbulent, heat transfer, etc.
7. Determine the material properties to be used,
8. Entering the boundary condition data for the pre-reshuffling core configuration in the form of the power of each fuel, the primary cooling water temperature enters the 30oC reactor core, the primary cooling water flow rate in the core of 775 GPM, the pressure in the primary pipe entering the reactor tank, and the properties Primary Cooling Water Physics.
9. Set the control parameters of solutions, such as: Under Relaxation Factors, Pressure Velocity Coupling, and Discrendary schemes,
10. Increals of Flow Medan,
11. Calculate/iteration,
12. Check the iteration results,
13. Storing iteration results,
14. If necessary, refine the grid then re -iterate to get better results,
15. Repeating stages 1 to stage 14 of the Post Resufting Core Configuration Gamble Model
16. Map the temperature in the core in the pre -reshuffling core configuration and post reshuffling.
17. Perform analysis

RESULTS AND DISCUSSION

Figure 3 is a geometry model and a reactor tank cross-section of the Gambit Program. This model is imported into a fluent program to be given the physical properties of cooling water, cooling water temperature and cooling water rate into the reactor tank, fuel data. Furthermore, the running program is carried out.

The calculation results that have been carried out by the Fluent Program on the 2000 Triga reactor model with the pre-reshuffling core configuration and the post-reshuffling core configuration obtained a reactor temperature map of each configuration in the 500 kW reactor power, displayed in Figure 4.

In Figure 4 it can be seen that in the pre-reshuffling core configuration, it is known that there are 9 positions of sub-cooled boiling) in the triga 2000 reactor core with the fuel surface temperature value above the cooling saturation temperature in the core 112.4 °C, namely in the positions of B3, B4, B5, B6, D4, D6, D8, D10, and D12. The maximum temperature is in B5 with a maximum surface temperature of a fuel clay of 126.41 °C



(a) (b)

Figure 3. (a) geometry, and (b) cross section of triga reactors 2000 gambit results

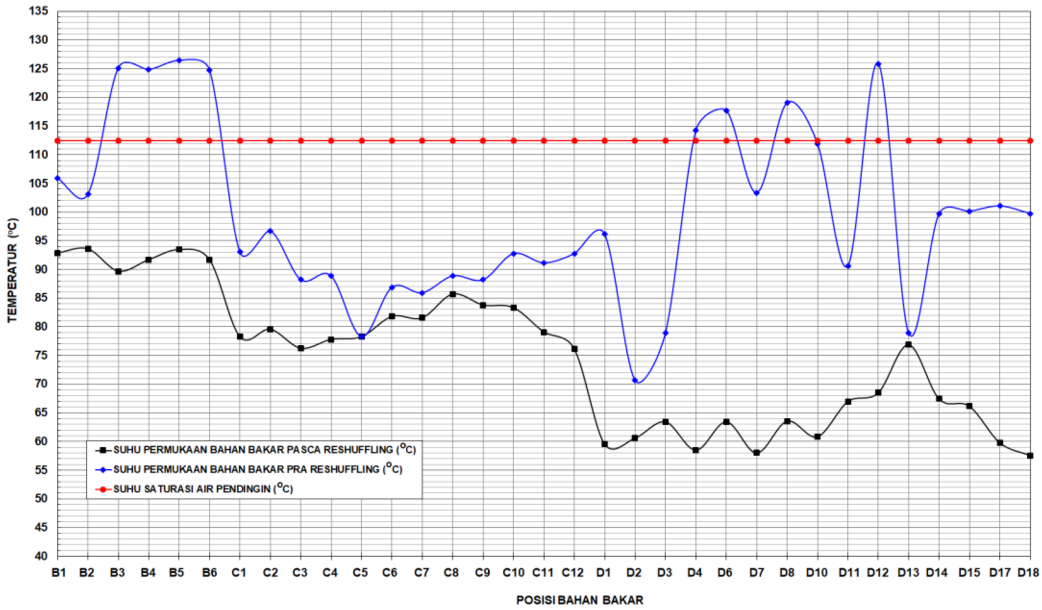


Figure 4. Fuel surface temperature in the reactor core fuel configuration of the pre and post reshuffling

This situation corresponds to the conditions that occur when the Triga 2000 reactor is operated at 500 kW power and observe the presence of bubbles that come out of the reactor's core.

In Figure 4 it also appears that, when using the Post Reshuffling core configuration with a reactor power of 500 kW, no sub-cooled boiling is found in the positions inside the reactor core. All fuel has a fuel surface temperature value below the cooling saturation temperature in the core, where the maximum temperature is in the B2 ring with a maximum surface temperature of the fuel surface of 93.55 °C. So it can be said that using the fuel configuration in the post-reshuffling core is able to eliminate sub-cooled boiling that previously occurred when using the pre-reshuffling core configuration. This condition would certainly be different when the Triga 2000 reactor with the Post-Reshuffling core configuration was operated on power above 500 kw. The possibility of sub-cooled boiling (sub-cooled boiling), but at least with this post-reshuffling core configuration is able to eliminate sub-cold boiling that previously occurred when the reactor was operated at 500 kW power using the pre-reshuffling core configuration.

CONCLUSION

The results showed that the operation of the 2000 Triga reactor in 500 kW power using the 105 fuel configuration in the pre-reshuffling core there were 9 sub-cooled boiling positions, namely in the positions of B3, B4, B5, B6, D4, D6, D8, D10, and D12, while in the configuration of 105 fuel in the porch after reshuffling there is no more sub-cooled boiling, so it can be said that in the fuel configuration in the porch after reshuffling capable Eliminating the occurrence of sub-cooled boiling in the core when the reactor is operated on 500 kw power.

Further research needs to be carried out to determine the maximum power value of the 2000 triga reactor, which can be operated with post-shuffling fuel configuration.

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REFERENCES

1. Sularso. Pompa dan Kompresor: Pemilihan Pemakaian dan Pemeliharaan. Pradyna Paramita. Jakarta. 2000
2. Rashidi S, Hormozi F, Sarafraz M.M. Fundamental and subphenomena of boiling heat transfer. *J Therm Anal Calorim* (2020). https://doi.org/10.1007/ s10973-020-09468-3
3. Steinhauser G, Villa M, Dihydrogen gas emission of a 250 kWth research reactor,

Applied Radiation and Isotopes 69 (2011) 1618-1620

4. Ramshesh V. Safety aspects of radiolytic gas generation in reactors. Sci. Prog. Northwood, UK. 2001. 84; 69–85.
5. Takiguchi H, Ullberg M, Uchida S. Optimization of dissolved hydrogen concentration for control of primary coolant radiolysis in pressurized water reactors. J. Nucl. Sci. Technol. Tokyo, Jpn. 2004. 41. 601–609.
6. Wang MY, Yeh TK, Chu CF, Chang C. Predicted impact of core flow rate on the corrosion mitigation effectiveness of hydrogen water chemistry for Kuosheng boiling water reactor. Nucl. Eng. 2009. 239, 781–789
7. Annonymous. Safety Analysis Report for UpGrade of TRIGA Mark II Reactor at Center for Nuclear Techniques Research. Bandung, Indonesia. 1996.
8. Luka S, Matjaz R. Power peakings in mixed TRIGA cores, Proceedings of The International Conference Nuclear Energy for New Europe, 2006
9. Prasetyo B. Kajian Perhitungan Faktor Puncak Daya Aksial Pada Skenario Reshuffling dan Refueling Teras TRIGA 2000. Dokumen No. R 170/RN 00 01/SNT 4. Baandung. 2018
10. Prasetyo B. Program Kegiatan Reshuffling dan Refueling Teras TRIGA 2000 TA 2020. Dokumen No. R 214/RN 00 01/ SNT 4. PSTNT BATAN. Bandung. 2020
11. Anwar IR, Indra S, MI Satryo. Simulasi karakteristik aliran dan suhu fluida pendingin (H2O) pada teras reaktor nuklir SMR (Small Modular Reactor), Jurnal teknik Mesin ROTASI. 2013. 15(4): 33−40
12. Pandey, A.K., 2011, A Computational Fluid Dynamics Study of Fluid Flow and Heat Transfer in a Micro Channel, Tesis Program Magister, National Institute of Technology Rourkela, India. 2011.