Transactions of the Korean Nuclear Society Spring Meeting
Gyeongju, Korea, May 29-30, 2008

Analysis of Fission Gas Release in LWR UO_2 Fuel under RIA Conditions Using Artificial Neural Network

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1. Introduction

When a LWR UO_2 fuel is subjected to reactivity initiated accident (RIA) conditions, one important concern is a significant fission gas release (FGR) because it can increase the fuel rod internal pressure and hence could cause fuel failure by increasing the load to the cladding. Therefore, accurate prediction of fission gas release is necessary in analyzing fuel behavior under RIA conditions.

With the available data in the open literature on fission gas release in LWR UO_2 fuel during RIA, a model is developed which can predict fission gas release under RIA conditions using parameters such as fuel burnup, pulse width, peak enthalpy, and fission gas release during base irradiation. These parameters are considered because they either affect the fission gas inventory available for release or determine the release paths that are operable during RIA.

2. Parameters affecting fission gas release

In this section, four parameters that are considered to affect FGR during RIA are chosen and discussed from the viewpoint of why and how they affect gas release.

2.1. Pellet average burnup

It is experimentally revealed [1] that during RIA majority of the fission gas is released from the grain boundary due to grain separation and subsequent pellet fragmentation caused by the rapid thermal expansion of intergranular gas bubbles. Therefore, pellet average burnup, which would determine fission gas inventory available for release in the grain boundary, is one of the important parameters that must be considered. Generally speaking, the higher the burnup, the more gas would be released.

2.2. Pulse width

The main consequence of pulse width during an RIA is that narrow pulses are more adiabatic than broader pulses, resulting in larger fuel enthalpy and higher fuel temperature [2]. Therefore, the narrower the pulse width, the more fission gas is expected to be released through grain separation and pellet crack that would be caused by the rapid thermal expansion of the gas bubbles in the grain boundary.

2.3. Peak fuel enthalpy

Peak fuel enthalpy is the maximum amount of energy deposited in a fuel rod during RIA conditions. A high peak enthalpy would generally produce high fuel temperature leading to higher gas release by the same mechanism as in the case of narrow pulse width.

2.4. FGR during base irradiation

Under the assumption that only fission gas retained in the grain boundary would be released during RIA because it lasts for only a few microseconds and hence there would not be enough time for the fission gas in the matrix to diffuse to the grain boundary, it is expected that if the fission gas release during base irradiation was high the amount that could be released during RIA would be reduced. However, on the contrary, tests with fuels having higher base irradiation gas releases showed higher gas release during RIAs [3]. This is perhaps because the interconnected release network that had been formed during base irradiation could also have acted as a release path during RIA, enhancing gas release.

3. Prediction of FGR using ANN

An artificial neural network (ANN) is used to develop a model which predicts a fission gas release under RIA conditions as a function of four parameters described above; pellet average burnup, pulse width, peak fuel enthalpy and fission gas release during base irradiation.

The ANN, often just called a neural network, is a mathematical model or computational model based on biological neural networks. In more practical terms neural networks are non-linear statistical data modeling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data.

Of the 35 FGR data for the RIAs, 16 of them were used to find the pattern by which each parameter has an effect on the FGR. Then using the pattern revealed by the ANN model, 19 data was used to check on how well the model predicts the measured value. It can be seen that while about a half of the 19 data was predicted within the uncertainty of ±6%, the other half was outside of this range. This implies that either the present ANN model needs to be improved or the number of data is not large enough to yield a reasonable model.

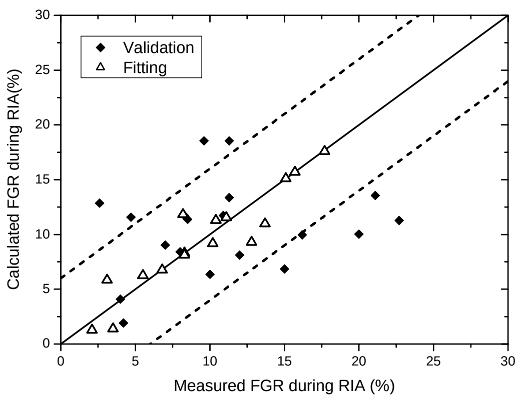

Fig. 1. Comparison of the FGR predicted by the ANN model with the measured values.

4. Sensitivity of the model

Fig. 2 shows the sensitivity of the ANN model for each parameter. For example, with other three parameters being fixed at average values, for the pellet burnup which is one standard deviation away from the average one of the 16 data used for finding the pattern (fitting), the present ANN model yields a FGR value that is 3% higher or lower than that calculated by the model with all four parameters having the average values. Therefore, it can be concluded at the moment that the effect of pulse width on gas release during RIA is the highest of the four parameters.

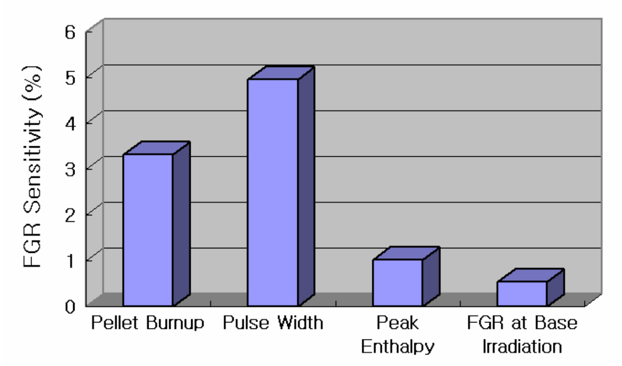

Fig. 2. Sensitivity of the ANN model for each parameter that is one standard deviation away from its average one.

5. Conclusion

By using an artificial neural network (ANN), a model was developed that can predict fission gas release under RIA conditions in terms of pellet average burnup, pulse width, peak enthalpy and FGR during base irradiation.

Acknowledgements

The Ministry of Education, Science and Technology (MEST) of the Republic of Korea has sponsored this work through the Mid- and Long-term Nuclear R&D Project.

REFERENCES

[1] Wenfeng Liu et al., Proc. Int. Topl. Mtg. LWR Fuel Performance, Salamanca, Spain, 22-26 October, 2006, pp.401-405.
[2] R.O. Meyer, Nucl. Tech. 155 (2006) 293.
[3] T. Nakamura et al., Nucl. Tech. 138 (2002) 246.