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Accuracy improvement of SPACE code using the optimization for CHF subroutine

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1. Introduction

Typically, a subroutine to calculate the CHF (Critical Heat Flux) is loaded in code for safety analysis of nuclear power plant. CHF subroutine calculates CHF phenomenon using arbitrary condition (Temperature, pressure, flow rate, power, etc). When safety analysis for nuclear power plant is performed using major factor, CHF parameter is one of the most important factor. But the subroutines used in most codes, such as *Biasi* method, etc., estimate some different values from experimental data. Most CHF subroutines in the codes could predict only in their specification area, such as pressure, mass flow, void fraction, etc. Even though the most accurate CHF subroutine is used in the high quality nuclear safety analysis code, it is not assured that the valued predicted values by the subroutine are acceptable out of their application area. To overcome this hardship, various approaches to estimate the CHF have been examined during the code developing stage of SPACE. And the six sigma technique was adopted for the examination as mentioned this study. The objective of this study is to improvement of CHF prediction accuracy for nuclear power plant safety analysis code using the CHF database and Six Sigma technique. Through the study, it was concluded that the six sigma technique was useful to quantify the deviation of prediction values to experimental data and the implemented CHF prediction method in SPACE code had well-predict capabilities compared with those from other methods.

2. Methods and Results

In this section some of CHF subroutines used in various codes and Six-Sigma technique are described.

2.1 Improvement process

Step1: Difference occurred between CHF experimental data and CHF prediction model (CHF subroutine loaded in SPACE code).

Step2: Deterioration for reliability and accuracy of SAPCE code

Step3: Review/improvement for CHF prediction model loaded in SPACE code including various CHF prediction model.

Step4: Error Minimizing throughout optimization for selection of correlation and improvement for subroutine logic.

Step5: Enhancement of reliability and accuracy throughout advancement of CHF prediction calculation.

Finally, error of CHF experimental data and CHF prediction model is 10^{-1} in present. But that error will be reduced by 10^{-4} using the Six-Sigma technique.

2.2 Six-Sigma technique

Six-Sigma technique is a business management strategy originally developed by Motorola, USA in 1981. As of 2010, it enjoys widespread application in many sectors of industry, although its application is not without controversy. Six-Sigma seeks to improve the quality of process outputs by identifying and remove the causes of defects (errors) and Minimizing variability in manufacturing and business process. It uses a set of quality management methods, including statistical, and creates a special infrastructure of people within the organization ("Black Belts", "Green Belts", etc.) who are experts in these methods, each Six-Sigma project carried out within an organization follows a defined sequence of steps and has quantified targets. These targets can be financial (cost reduction or profit increase) or whatever is critical to the customer of that process (cycle time, safety, delivery, etc.).

The term *Six-Sigma* originated from terminology associated with manufacturing, specifically terms associated with statistical modeling of manufacturing processes. The maturity of a manufacturing process can be described by a *sigma* rating indicating its yield, or the percentage of defect-free products it creates. A six-sigma process is one in which 99.99966% of the products manufactured are free of defects, compared to a one-sigma process in which only 31% are free of defects. Motorola set a goal of "Six-Sigma" for all of its manufacturing operations and this goal became a byword for the management and engineering practices used to achieve it.

2.3 Normalization verification for Biasi Model

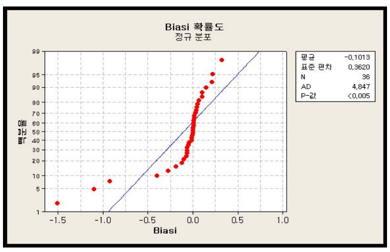

Fig. 1. Normalization distribution of Biasi Model

At first, normalization distribution of *Biasi* Model loaded in the SPACE code was analyzed using the *MINITAB* program for Six-sigma analysis. P-value indicates that *Biasi* Model does not enough to predict CHF phenomenon exactly in Figure1. Also, average value and sigma value (z-bench) of *Biasi* capability were analyzed. That value is -0.101255 and -0.81σ respectively.

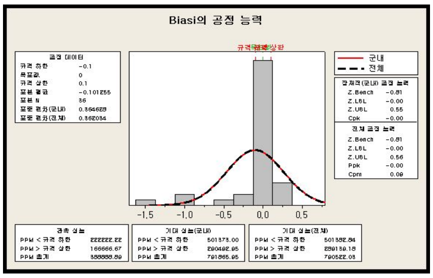

Fig. 2. Average value and sigma value for *Biasi* Model

Therefore we must establish the CFH database to predict for over all area without conserving specific area.

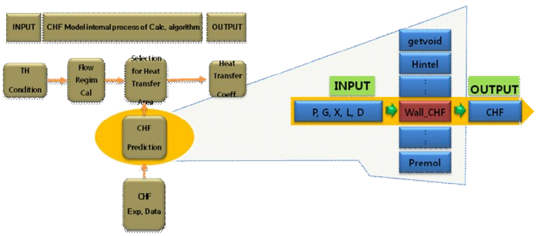

Fig. 3. Improvement of CHF calculation logic

Figure 3 indicates that internal structure of CHF calculation logic to improve.

2.4 Design

Major factors (pressure, flow speed, diameter of pipe, length of pipe) affecting to CHF prediction model were selected using the Payoff Matrix. Finally, diameter and length of pipe factor is selected by considering effectiveness and difficulty for analysis.

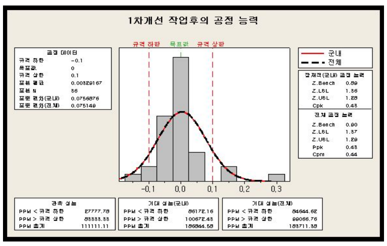

Fig. 4. Average value and sigma value after using Payoff Matrix

After selection for above two factors, average and Sigma value (Z-bench) were evaluated. That value is -0.00329716 and -0.89σ respectively.

It is not enough to meet the average value (below 10^{-4} or 3.0 σ). So, re-analysis was performed using the experimental plan method of Six-Sigma Methodology.

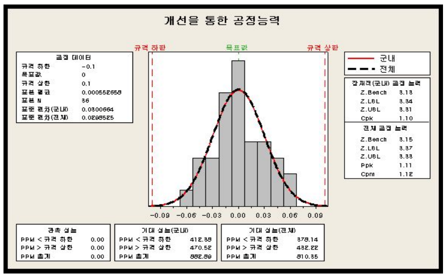

Fig. 5. Average value and sigma value after using Experimental Plan Method

Analysis result using the Experimental Plan Method indicates that average and sigma value meets our final purpose. Average and sigma value are 0.55 * 10^{-4} and 3.13 σ respectively.

3. Conclusions

In this study, various CHF prediction models (subroutine model) were evaluated using the statistical technique. The most affecting factors to accuracy of safety analysis code for nuclear power plant were selected and evaluated in Six-Sigma technique. Generally, Six-Sigma technique is used to reduce inferior goods and error in the industry. But we confirmed that the Six-Sigma technique can be available in the enhancing accuracy of computer program or software. Finally, it was concluded that the six sigma technique was useful to quantify the deviation of prediction values to experimental data and the implemented CHF prediction method in SPACE code had well-predict capabilities compared with those from other methods.

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