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Article / Book Information

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Title(English)	Ultrasonic Pulse-Echo Measurement of Bubble Diameters in Suppression Pool
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種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 原子核工学	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Engineering)
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Suppression pools allow decreasing the pressure in a nuclear reactor or in the containment during an accident by condensing steam and also by venting the gas filtered by the pool. Radioactive particles are removed from the gas via a scrubbing effect, the efficiency of which depends on bubbles parameters such as the bubble diameter. The thesis describes the development of an ultrasonic technique that is capable of measuring bubble diameters in the suppression pool condition (increased temperature and pressure). The performance of the technique was tested and examined. As a result, the uncertainty of the technique was understood. This allows obtaining experimental bubble size data to improve the understanding of scrubbing efficiency.

First, the problematics of the scrubbing effect in suppression pools and the methods of predicting the scrubbing effect efficiency were studied using available literature and the importance of bubble diameter data was explained. Measurement techniques capable of measuring the bubble diameters were reviewed and the advantages of ultrasonic measurement (higher void fraction in large geometries as compared with optical techniques) were explained.

Then, a novel measurement technique capable of measuring the position of multiple bubble surfaces simultaneously was proposed. It overcame the limitations of traditional pulse-echo techniques by examining the shadow cast by a bubble and by choosing suitable transducer (TDX) parameters so that reflections from multiple bubbles can be recorded by the TDX and by developing a tracking technique capable of distinguishing between multiple bubbles. The developed technique was validated in an ideal experiment where the flow condition was simplified to allow easier comparison between the developed technique a high-speed camera (HSC). It was discovered that the technique is sufficiently accurate and while it does not detect all the bubbles which pass the measurement volume, the difference between a number of bubbles detected by the developed technique and by the HSC was sufficiently low in the tested range. The difference grows with void fraction which limits the developed technique to low void fraction bubbly flows.

Then, a method for measuring bubble diameters using the developed technique was introduced. The conversion between horizontal bubble lengths and bubble diameters was discussed in detail. The uncertainty analysis of the measurement was conducted. The method was validated by measuring diameters of metal cylinders as well as diameters of air bubbles in realistic experimental settings where HSC was used for a reference measurement. The experiment required improving upon the video processing used for analysing videos recorded by the HSC by including an algorithm for recognition of overlapped bubbles and separating them and by adding a second HSC to evaluate the 3D position of bubbles. The results agreed within the predicted uncertainties.

Resistant TDXs were developed for the suppression pool environment of high temperature and pressure. Due to a lower sensitivity as compared to regular TDXs in room temperature, the ultrasonic pulse generation was tested in order to decide a suitable pulse generation condition ad a filtering scheme was introduced to decrease the noise. The developed technique was tested using the resistant TDXs by measuring diameters of metal cylinders and bubble diameters in realistic experimental settings. Two HSCs were used for a reference measurement of bubble diameters and the video processing was further improved. The comparison showed worse agreement than for regular TDXs, but it was still acceptable.

Finally, a suppression pool experiment and its instrumentation were introduced in detail. The experiment allows injecting a mixture of steam and air into a pool of water through a vertical downcomer. Some parameters of the experiment, such as the downcomer diameter, gas flow rate or pool volume were downscaled, while other parameters, such as pool water temperature and pressure, downcomer submergence and others were similar to real suppression pools deployed in nuclear power plants. The effect of temperature on the measurement results and on the measurement uncertainty was analysed and calibrated for. Finally, the resistant TDXs were used to measure bubble diameters under various experimental condition and the effect of pool temperature, steam flow rate, injection diameter and radial position on the bubble diameter distribution was examined. The results show the capability of the developed measurement technique and provide a useful insight into the bubble hydrodynamics in suppression pools and thus the efficiency of scrubbing.

Finally, the achievements of the dissertation were summarised, namely the development of a novel ultrasonic pulse-echo technique, the development of resistant transducers, the validation of the developed technique and the demonstration of the application of the developed technique to a bubble diameter measurement in a suppression pool experiment. The strengths and weaknesses of the developed technique were discussed and the guidelines for a future research were included.