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Fuzzy Logic Representation of Flow Regime Map of Two-Phase Flow

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1. Introduction

The water cooled nuclear power plants are often in the condition of two-phase flow during normal operation and hypothetic incident conditions. Its deterministic safety has been analyzed by the safety codes furnished by the two-fluid model(Ishii 1975). The interfacial transfer depends highly on the flow patterns in two-phase flow and its complicated relation of the flow regime and related constitutive models could be a cause of spurious instability when the flow condition is near the border of two flow regimes.

To enhance the prediction capability, confidence level of competing flow regimes is investigated in the present paper. Neural network is employed. For the feedforward neural network, the output nodes are excited differently, so we can produce the confidence level according to the degree of excitement (Lee and Ishii, 2006). But to remove the chance of subjective in the selection of the reference data for training the neural network, the self-organized neural network is employed.

2. Methods and Results

In this section the method used to construct the fuzzy representation flow regime map are presented including self organized neural network.

2.1 Self Organized Neural Network

A neural network with two layers is employed as a self organized neural network as shown in Fig 1. The self organized neural network has been developed.

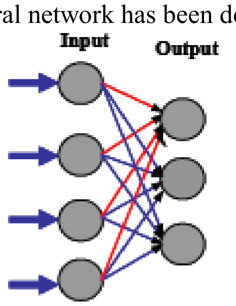


Fig 1. The Structure of Kohonen Self-Organized Map

2.2 Determination of the membership

The feed forward neural network quantifies confidence level of output nodes, so procedure to construct membership is relatively easy. However, SOM notifies only the winner node. Therefore, in the present study we determine the confidence using the voting method which determines the probability of appearance of a certain flow regime in a certain period of observation period. For instance, we can vote 60 times from the data of one minute when we divide data in one second period as shown in Fig.6. The flow patterns identified has a certain shape of distribution and it can be used as the the membership function .

After finding such a confidence level, we use the linear regression method to determine the fuzzy boundary with the 98% confidence level in the assumption that the transition has the linear dependency between the superficial liquid and gas velocities.

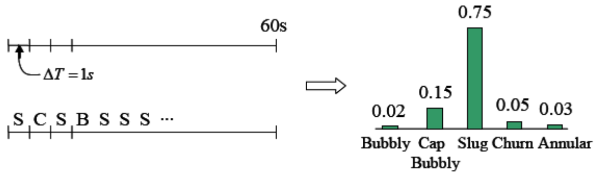
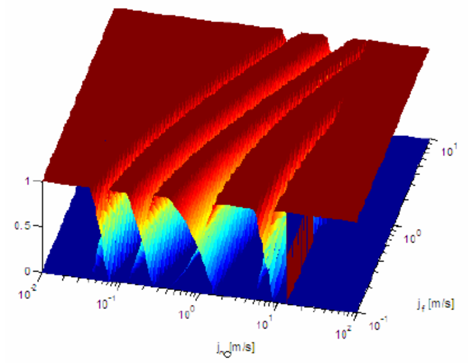


Fig 2. Voting method to determine the confidence level.

2.3 Fuzzy Flow regime map for the vertical upward flow in the pipe with ID of 25.4mm

The present method is applied to the data of the coccurent vertical two phase flow in the pipe with ID of 25.4mm. Since we set up five output nodes, the present Kohonen Neural network classified five flow regimes: discrete bubbly flow, cap bubbly flow, slug flow, churn flow, and annular flow. As shown in Fig. 3, flow regime map is represented in the space of the superficial gas and liquid velocity and confidence level.

Fig 3 showed the overlapped surface of the fuzzy membership functional flow regime map. It represents the confidence level change near the border of the flow regimes. Fig. 3(b) showed the contour map which is



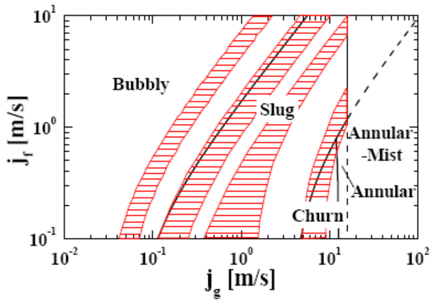


Fig 3. The 3-dimensional surface of the flow regime map and comparision between transition band and the Mishima-Ishii transition criteria for 25.4mm ID pipe.

correspondent with the traditional flow regime map. It showed clearly the transition regions are in between flow regimes. Previously these transition areas have been presumed arbitrarily but it is the first work to identify the transition area based on the experimental data and the objective decision method.

2.4 Fuzzy Flow regime map for the vertical upward flow in the pipe with ID of 50.8mm

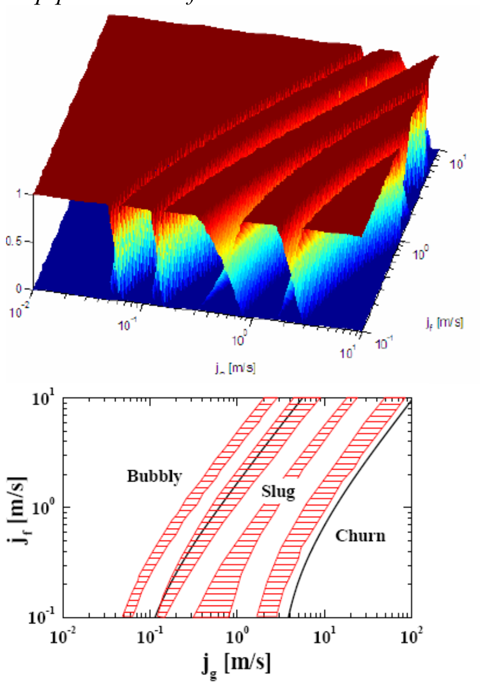


Fig 4. The 3-dimensional surface of the flow regime map and comparision between transition band and the Mishima-Ishii transition criteria for 50.8mm ID pipe.

Fig 4 shows the overlapped surface of the fuzzy membership functional flow regime map. It represents the confidence level change near the border of the flow regimes. In the Fig 4(b), comparison of the present result with the previous work is performed. The well known Mishima-Ishii model shows a good agreement with the present work. The transition of bubbly-and-slug is in side of the transition area between the cap bubbly and slug flow regime. It has been known that traditional flow regime identification has been made that bubbly flow includes cap bubbly flow as noted by Titel and Dukler. We also identify the transition of stable slug and unstable slug flow. As for the churn flow regime, the present flow regime map identify its transition in a little bit small gas superficial velocity than Mishima-Ishii requirement.

3. Conclusion

In the present study, a systematic method to construct a fuzzy membership function of flow regime which is capable of determining realistic interfacial transfer rate by fuzzy logic interpolation of competing values of flow regimes related. For this, the time sequential impedance data were harnessed from the vertical upward flow loop.

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