Critical angle for the inclined pipe to distinguish horizontal and vertical character

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1. Introduction

Safety analysis codes of nuclear power plant have equipped the flow regime map to provide the proper constitutive relations corresponding to the flow regime. Traditionally, the flow regimes for the vertical flow and horizontal flow have been investigated intensively and we have very reliable map and criteria to be useful for the computer code. However, for the inclined pipe, we have lack of experimental works and transition criteria to be used. Actually, in the pressurized heavy water nuclear reactor like CANDU, certain part of pipe line has inclination angle. At this moment the safety code such as RELAP-CANDU has no flow regime map for the inclined pipe, Engineering judgment intuitively suggested to take the reference angle and horizontal flow regime map for the inclined pipe with the lower angle than the reference and vertical flow regime map for the larger angle than the reference angle. Also, as the reference angle it has been suggested that 45 degree may compromise the difference of two dominant flow regime. However, it has no physical bases. Also, it casted fundamental questions on the drift flux model and the effect of gravity on the instability of two-phase flow. Therefore, the present study is designed to find the reference angle to distinguish the horizontal flow regime map and vertical flow regime map. The study was made based on the experimental way with the special intelligent identifier to remove any chance of human subjective perception.

2. Flow Regime identification

In the present study, we employ the self organized neural network to identify the flow regime in the objective way. The neural network only has two layers and it needs to define the number of cluster to be identified and number of input nodes. In the present study, we sort the impedance signals based on the amplitude and directly input to the input layer. This input is a kind of cumulative PDF and it is immune to the statistical requirement. The most remarkable feature of the present method is the capability of instantaneous decision. Fig. 1 shows the structure of the neural network and shape of input signals.

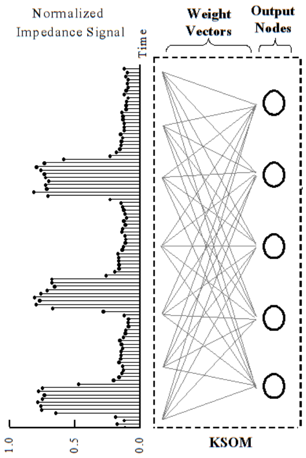

Fig. 1 The schematic structure of the neural network flow regime identification

3. Results and Discussions

The test has been made by changing the inclination angle from zero to 90 degree. Also, high speed camera was used to take the image of flow to tell which flow regime is corresponding to the cluster identified by the neural network. Figure 3 represent the flow regime identified for the horizontal flow, i.e 0 degree.

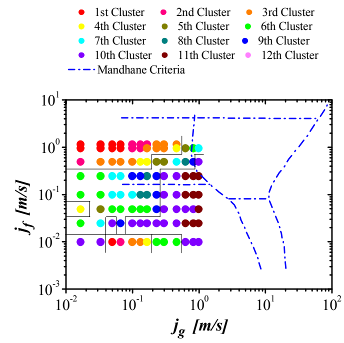

Fig.2 Flow regime of horizontal channel.

The 5^{th}~12^{th} circles are corresponding with the stratified flow. Large pressure drop only allow us the plug flow regime represented by the red circles. If we can apply high liquid phase flow, the turbulent eddies will break the plug into the many number of bubbles. Therefore, in the horizontal channel, we found only two flow regimes such as the plug flow and stratified flow in the present flow conditions.

3.1 Inclined angle between 90 and 2degree

Series of experiments were performed by changing the inclined angles. Actually, it has been observed in the very small angles below 10 degree, the flow regime was very similar to the vertical flow regime. As shown in Fig, 3, the flow regime maps identified were depicted.

As for the bubbly flow, Mishima Ishii transition line includes the discrete bubbles and cap bubbles. For the inclined pipe, some plugs are very similar to the cap bubbles in the vertical pipe. Surprisingly, Mishima Ishii's criterion is working to identify the bubble-slug transition. It can be easy to understand because the drift velocity of the drift model has the 1/4 power to the sine value of the inclination angle. The variation of the gravity effect on the drift velocity is negligibly small.

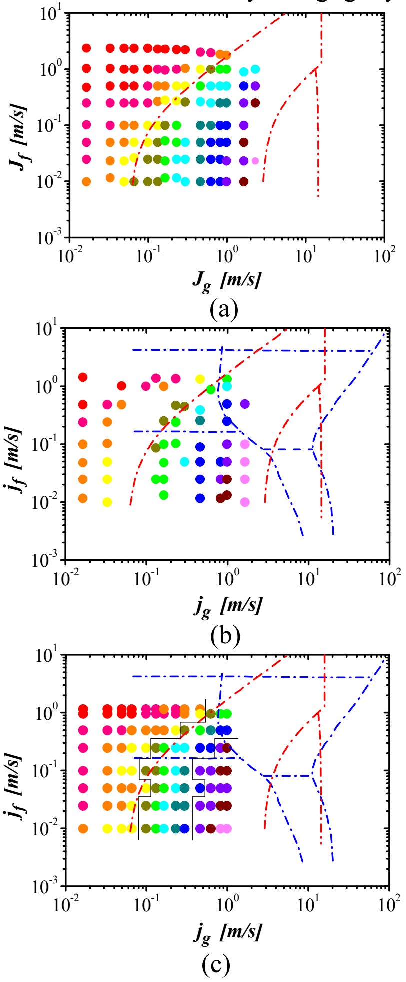

Fig. 3 Flow regimes for (a) 90, (b) 30, (c) 2 degrees

3.2 Critical angle

After finding that the small inclination of the pipe will change the horizontal flow regime into the vertical flow regime, we performed more tests to find the critical angle to distinguish the horizontal and vertical characters. The variation of angles we did was 0.1, 0.2, 0.3, 0.5, 1 and 1.5 degree. The flow regimes identified are shown in the Fig. 4. The horizontal flow regime is sustained up to 0.3 degree. However, the flow regime of from 0.5 degree shows big difference. Therefore we can say that the flow regime change may occur in between 0,3 and 0.5 degree. It is somehow noticeable that Barnea suggested 0.25 degree as the critical angle. However, in that period, the flow regime identification was made based on the heurisitic observation. Therefore, it was found that in the current study, the critical angle is little bit larger than that of Barnea et al.

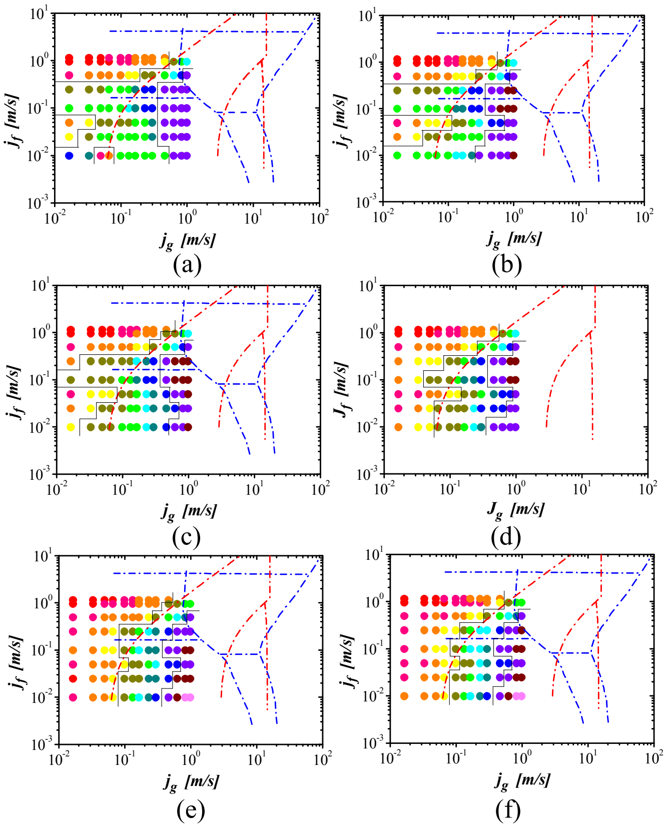

Fig.4 The flow regime of small inclination angles; (a) 0.1, (b) 0.2, (c) 0.3, (d) 0.5, (e) 1, (f) 1.5 degrees

4. Conclusions

With the neural network and objective flow regime identification method, in the present study, we tried to find the critical angle distinguish the horizontal flow regime and vertical flow regimes. As Barnea noted, the critical angle was extremely small as 0.25. In the present study, we found that the critical angle is the value in between 0.3 and 0.5. Therefore, almost all cases of the inclined two-phase flow the vertical flow regime criteria to distinguish the bubbly flow and slug flow. However, even though the transition criteria is vertical like, the constitutive relation should be made based on the horizontal flow because, the nose of the bubble always contacting the upper part of the pipe which is very common in the horizontal pipe.

REFERENCES

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