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Study on the Pressure Drop in the Helical Wire Inserted Tube Using FLUENT Code

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1. Introduction

Bubble departure from the surface is an important physical phenomenon in flow boiling CHF especially in subcooled and low quality region. It is necessary to remove the bubbles near the wall surface because relevant escape of bubble from the heated wall makes the maximum heat removal, the CHF increase. It is possible to remove bubbles on the inner surface of the tube wall by the centrifugal force due to the swirl flow using swirl flow generators such as wire coils, ribs and twisted tapes.

It is known that the heat transfer coefficient and the critical heat flux are improved when swirl flow generators are used. However, at the same time, an increase of the energy consumption in the entire system is generated, because the flow resistance also increases. In the turbulent flow inside a wire inserted tube, the laminar sub-layer is disturbed by the wire, which increases the friction and thereby the pressure drop. In this context, only when the increased CHF is profitable compared to the increased pressure drop, the use of swirl generator is justifiable.

The purpose of this study is to clarify the effect of an inserted helical wire tube on the pressure drop in the tube and optimize the effect of swirl generator in balancing pressure drop and swirl generation. Pressure drop is calculated using computational flow dynamics code, FLUENT, as the pitches and the wire diameters are varied. The working fluid is water with 0.01m inner diameter tube, which is the similar one with the actual annular fuel size. The calculated results are compared with the correlation based on experimental data.

2. Prediction of the pressure drop

Data from frequently referred investigations were gathered by T.S.Ravigururajan [1] for a wide range of tube parameters. These are 0.01-0.2 for e/d, 0.1-7.0 for p/d and 0.3-1.0 for α/90. In the analysis using FLUENT code, range of the tube parameters which would be used were modified as 0.15 for e/d, 4.0-6.0 for p/d and 0.29-0.41 for α/90 based on the 0.01m tube inner diameter.

The turbulent k-ε model was chosen for the FLUENT code calculation. The wall friction factor was calculated from the case of a tube without wire and this friction factor was used for other calculations.

For the comparison with this computational result, the friction factor correlation (eq (1)-(2)) which was given by T.S. Ravigururajan [1] was used to evaluate the pressure drop through the wire inserted tube.

$$f_a / f_s = \Big\{ 1 + \Big[29.1\mathrm{Re}^{(0.67-0.06p/d-0.49\alpha/90)} \times (e/d)^{(1.37-0.157p/d)} \times (p/d)^{(-1.66\times10^{-6}\mathrm{Re}-0.33\alpha/90)} \times (\alpha/90)^{(4.59+4.11\times10^{-6}\mathrm{Re}-0.15p/d)} \times (1+2.94\sin(\beta/n)\Big]^{15/16} \Big\}^{16/15} \qquad (1)$$

where $f_s = (1.58 \ln \mathrm{Re} - 3.28)^{-2}$ (2)

f_a = friction factor of tube with wire,
f_s = friction factor of smooth tube,
p/d = wire pitch to tube diameter ratio,
e/d = wire diameter to tube diameter ratio,
α/90 = helix angle ratio and
β/n = wire geometry (=0 in this study).[4]

The augmented tube friction factor depends on the wire diameter, pitch of helical wire, helix angle of the helical wire, and Reynolds number, among other variables.

3. Result and discussion

The pressure drop was calculated for the different pitch values and different velocities. As shown in the figure 1 and 2, swirl flow was generated due to the insert of a wire. As one can expect, in the consideration of the radial velocity range distribution at the end of the outlet, the smaller pitch value and the larger water velocity, the larger radial velocity was resulted.

The comparison of these results which are from the FLUENT code calculation with the results from the calculation using the equation (1) is shown in the Table 1. As you can see, the pressure drop increases as the pitch value decreases in both results. However, FULENT code results shows larger values than the results from the correlation.

Figure 1. Radial velocity distribution in the wire inserted tube with e=0.0015(m), p=0.06(m), and v=1(m/s)

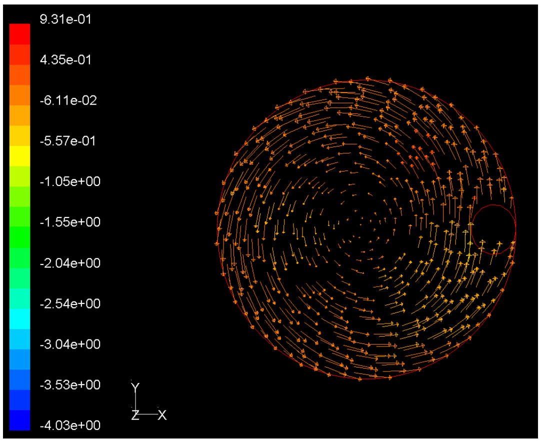

Figure 2. Radial velocity distribution in the wire inserted tube with e=0.0015(m), p=0.04(m), and v=2(m/s)

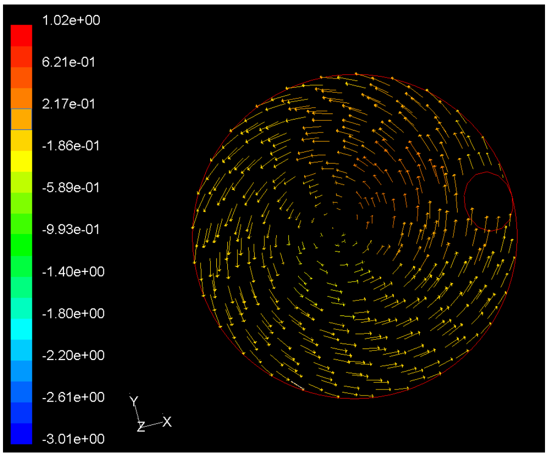

Table 1. Comparison of the pressure drop calculation

Pitch (m)	Velocity (m/s)	Equation Result(Pa/m)	FLUENT Result (Pa/m)
no	1	408.0677	500.0102
0.06	1	607.9415	1175.947
	2	2018.5794	2341.915
0.04	1	1033.2158	-
	2	3601.395	2940.495

The main reason can be the difference between friction factors. For the FLUENT calculation, friction factor is just related to the wall surface roughness. However, in the correlation of equation (1), not only the surface wall roughness but also the wire itself were considered as the surface roughness.

FLUENT calculation gives reasonable pressure drop values compared to the correlation. Using FLUENT, the detailed information about flow fields and swirl flow can be obtained and these give clue to the resulted CHF value in the view point of bubble departure or void distribution.

4. Conclusion

. From the works above, even though the result from FLUENT code shows larger value, the pressure drop shows the similar trend between two methods. In the future, it is necessary to perform this work with different wire diameters or pitch values to understand more exact difference. Moreover, void fraction distribution with inserted wire will be investigated. Then, finally, optimized wire geometry can be produced through these works.

REFERENCES

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