Characteristics of Pressure-increasing for Self-sustained Oscillation in Grooved Channels

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The characteristics of pressure-increasing for self-sustained oscillations in grooved channels were investigated experimentally. Time-varying local pressures were measured under different pressure-increasing conditions with the pressure sensor, and the effects of different pressure-increasing operation on the local pressure were also discussed. The local pressure signal showed that there exists an effective range for increasing pressure, and with the increment of the internal pressure in the grooved channel, the self-sustained oscillation will appear in the higher flow rate, contrast to that of no pressure-increasing. It is seen that the optimum values of pressure-increasing are different each other for the self-sustained oscillatory flow. Moreover, it is also found that the efficient influence of pressure-increasing on the internal pressure exists in the lower flow rate. The above results are very significant to decide the operating conditions of the efficient heat exchanger in practical engineering.

Key Words: Optimum Value, Pressure-increasing, Self-sustained Oscillation, Grooved Channe1

1. Introduction

It must be an eternal topic to develop and utilize the new clean energy. As an important approach to realize this purpose, more and more efforts are worth to devote to the study of the ocean thermal energy conversion (OTEC) system. As a fundamental element of the plate heat exchanger, the performance of fluid flow and heat transfer in the two-dimensional channels should be further clarified.

Recently, many studies were carried out in the two- dimensional channels, including the plane channel[1], the grooved channel[2~4], the wavy channel[5] and so on. The previous study results brought out the strength characteristics of the self-sustained oscillations in the grooved channel[6] clearly, and then the effects of the pressure-increasing operation on the amplitude of the self-sustained oscillation had been fully described. It seems that there must have an optimum value of pressure-increasing, at which, the maximum strength of self-sustained oscillation and the optimum heat transfer rate will be obtained. This prediction will be very significant for the practical enhancement operation of the plate heat exchanger.

In this study, the characteristics of pressure-increasing for the self-sustained oscillations will be detected experimentally, and more features, including the optimum value and the influence of pressure-increasing on the internal pressure, will be clarified.

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2. Experimental setup

The experiments are carried out with the same apparatus as before[6], as showed in Fig.1. The flow is provided by a centrifugal pump and the city water is used as the working fluid. The flow rate is adjusted by the control valve and is measured with an electro-magnetic flowmeter; Q represents the flow rate. Five pressure sensors are used to measure the local time-varying pressure. The valve-1 and valve-2, which are located at the outlet of the test section and the downstream of the flowmeter respectively, are used to obtain the decreasing or increasing pressure operating condition.

The dimensions of the test section are shown in Fig.2. Total six kinds of grooved channels, with the period length L=20mm, W=200mm, h=2.5mm and the grooved lengths l=4,6,8,10,12,14mm, are used in this study. To process the data conveniently, the pressure-increasing value is represented by the change of the flow rate.

Considering the effects of the entrance length, all of experimental data are captured from the downstream of the grooved channel. Moreover, the flow characteristics in all grooved channels have the similar tendencies, thus the representative experimental results in the channel l=10mm are mainly discussed here.

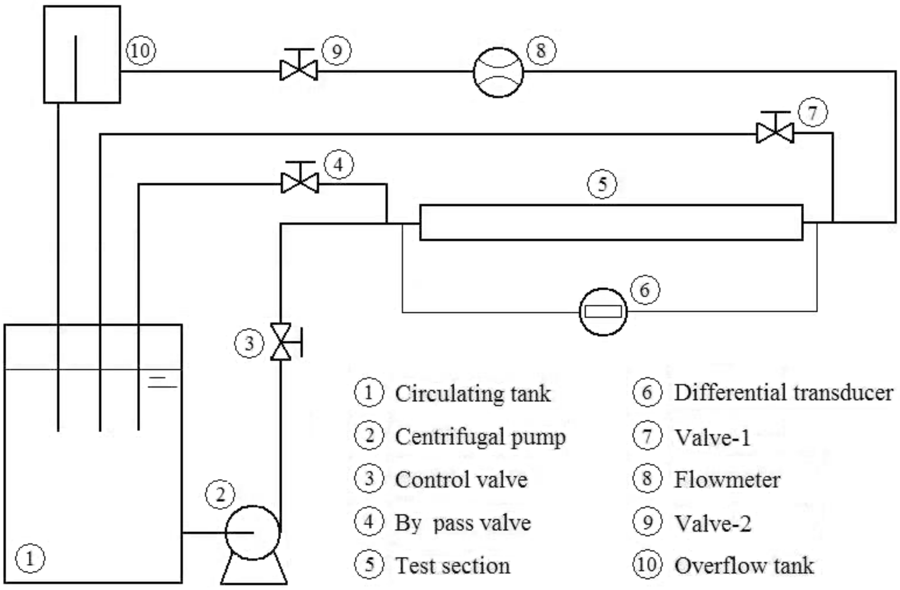

Fig. 1 Schematic diagram of the experimental system

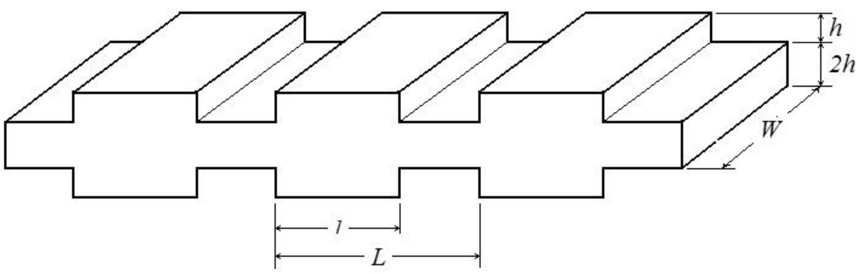

Fig. 2 Dimensions of the test section

3. Results and discussion

3.1 Self-sustained oscillation

To decide the operation condition of the pressure-increasing, the flow regime, in which the self-sustained oscillation appears, is first examined. Fig.3 shows the representative pattern of self-sustained oscillation when Q=340ml/s, which is recorded by the pressure sensor. Obviously, it is easy to detect the oscillation in this way. With a mathematical filter processing, the amplitudes of the self-sustained oscillation in whole flow regime are obtained, as showed in Fig. 4. It is sure that the self-sustained oscillation mainly appears in the regime Q=280~360ml/s under no pressure-increasing operating condition.

3.2 Effective range of pressure-increasing

Based on a large number of experiments it is found that the pressure-increasing operation is not valid in all range. The most effective flow range is when Q=330~360ml/s, i.e. at the later period of the self-sustained oscillation, Fig.5 shows this phenomenon clearly. Moreover, the amplitudes sensitive to the pressure-increasing

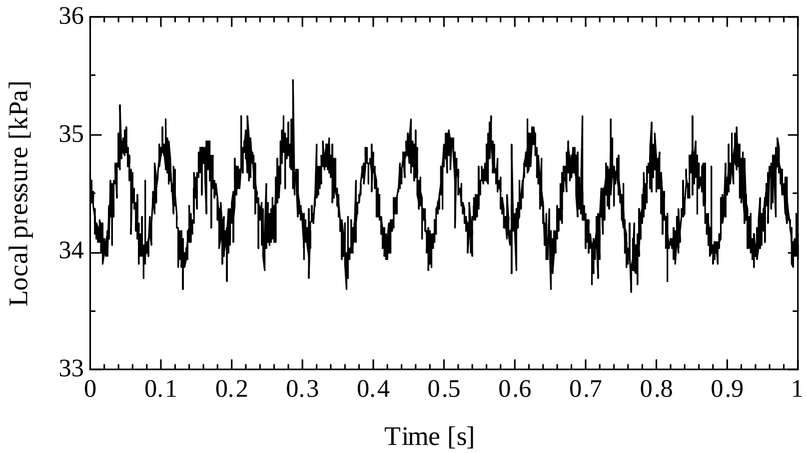

Fig. 3 Self-sustained oscillation at Q=340ml/s

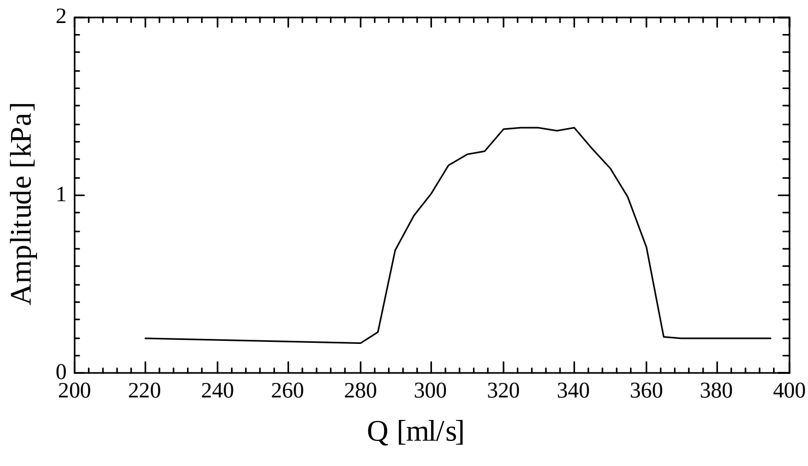

Fig. 4 Amplitude of self-sustained oscillation for whole flow regime

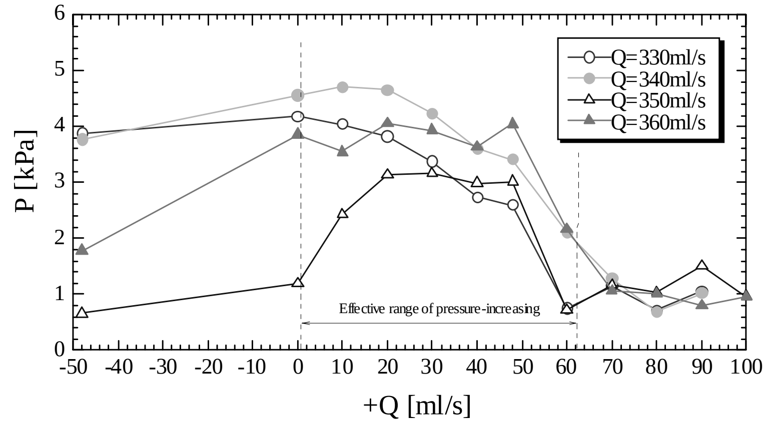

Fig. 5 Sensitive range to pressure-increasing

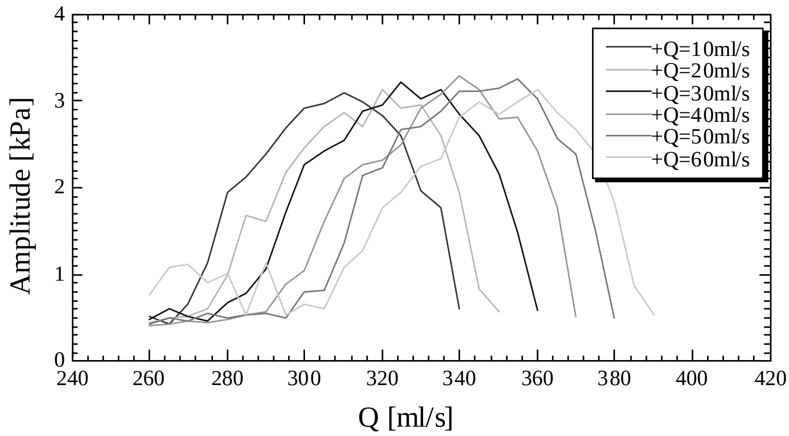

Fig. 6 Relationship between the amplitude and the flow rate

operation is found to exist in the range of pressure-increasing flow rate +Q=10~60ml/s. Then the optimum value of pressure-increasing will be explored under this range of pressure-increasing flow rate.

3.3 Effective of pressure-increasing operation on the self-sustained oscillation

With the pressure-increasing operation (+Q=10~60 ml/s), the relationships between the amplitude and the flow rate are drawn in Fig.6. It is seen that the amplitudes become higher than no pressure-increasing. Furthermore, the emergence of flow rate for the self-sustained oscillation is delay with the increment of pressure-increasing. On the other hand, the maximum amplitude corresponding to every flow rate is different under different pressure-increasing condition; it means that there is not a fixed optimum value for different pressure-increasing operation.

3.4 Optimum value of pressure-increasing

To get the optimum value of pressure-increasing, the peak amplitudes under different pressure-increasing conditions are checked. Corresponding to the flow rate, the relationships between the amplitude and the pressure-increasing value are showed in Fig.7. It could be seen clearly that there exits an optimum value of pressure-increasing for different operating condition. Table 1 lists the optimum value of pressure-increasing vs.

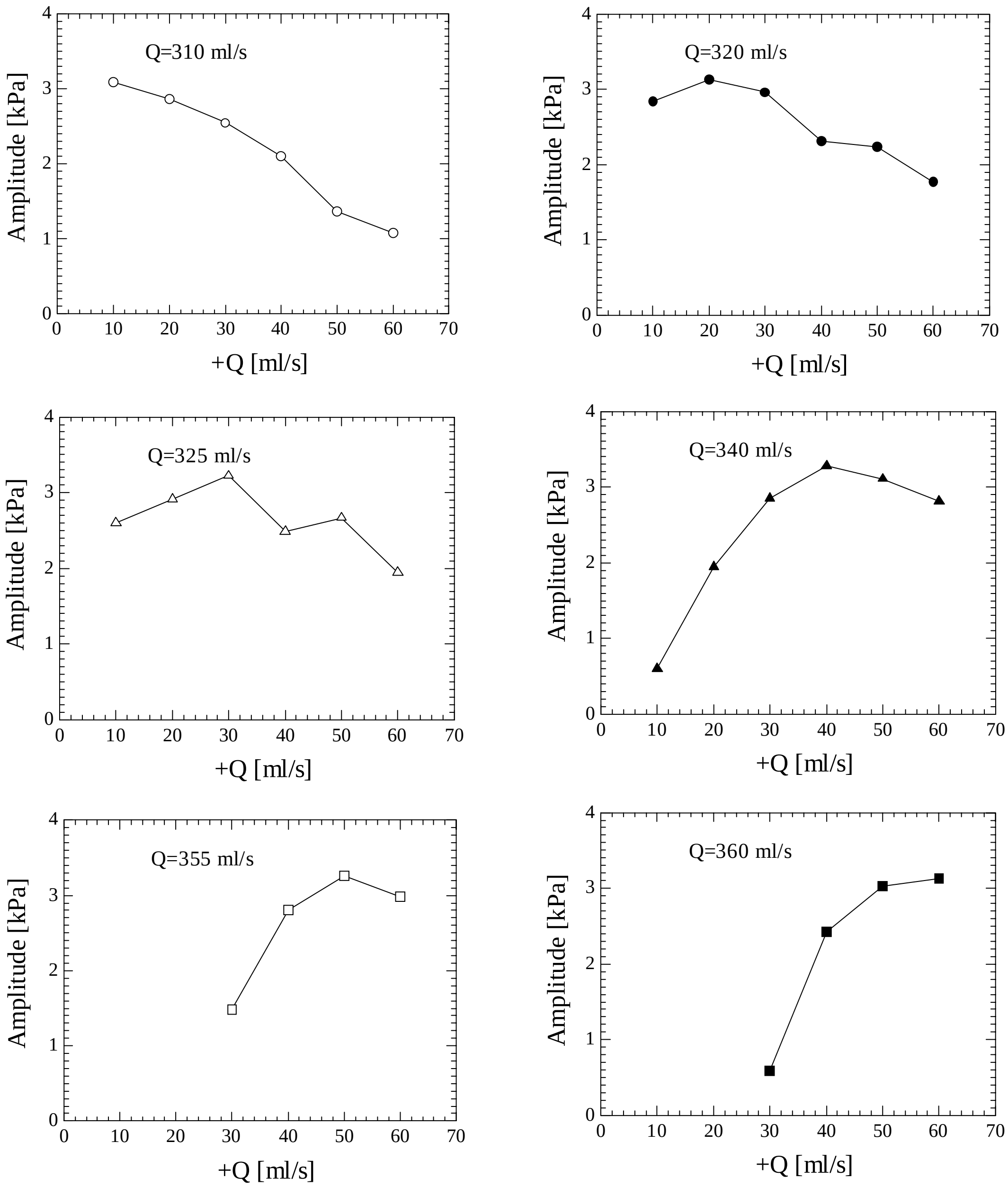

Fig. 7 Amplitude vs. +Q at Q=310~360ml/s

different flow rate. According to the data in this table, the relationship between the optimum value of pressure-increasing and the flow rate is displayed in Fig.8, that is, approximately, the optimum +Q increases linearly with the flow rate of the self- sustained oscillation. This result will become an important reference to the practical operation for the heat exchanger.

3.5 Sensitivity of pressure-increasing operation

With the increment of Reynolds numbers, the effects under different pressure-increasing conditions are showed in Fig. 9. For the no pressure-increasing condition P0, the internal pressure of the channel increases gradually, approximately in linear. But for the pressure-increasing conditions from P+10 to P+70, the internal

Table 1 Optimum value of pressure-increasing and flow rate of self-sustained oscillation

Q(ml/s)	310	320	325	340	355	360
+Q(ml/s)	10	20	30	40	50	60

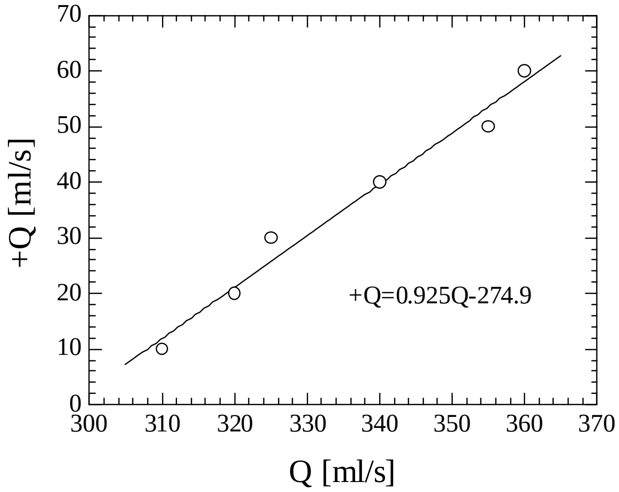

Fig. 8 +Q vs. Q

pressure of the channel increases with the increment of the value of the pressure-increasing. Furthermore, it is clearly seen that compared with the pressure at the higher Reynolds number, the good effects of pressure-increasing could be obtained at the lower Reynolds number. To easily confirm the above phenomena, the difference values between each pressure-increasing value and that with no pressure-increasing are calculated and the relationship between these difference value and the Reynolds number are showed in Fig. 10. Obviously, the effects of pressure-increasing decline rapidly, the good effects could be found only before Re<1000.

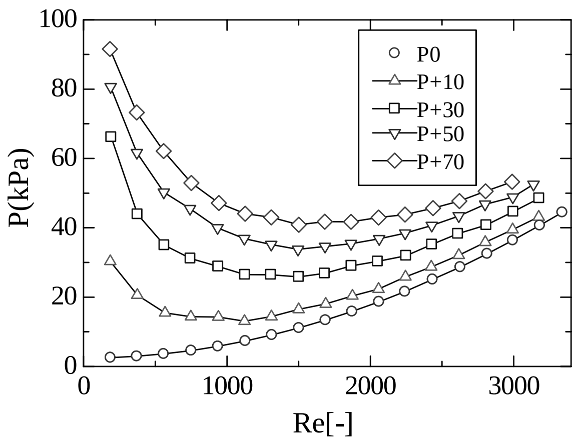

Fig. 9 Effects of pressure-increasing operation at different Reynolds numbers

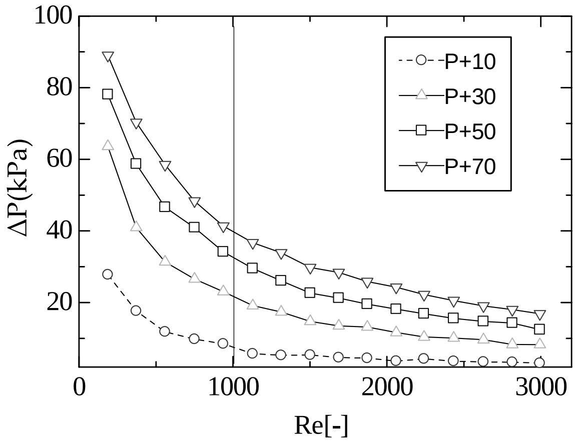

Fig. 15 Relationships between the differences value of pressure-increasing and the Reynolds number

4. Conclusions

In the present study, the optimum value of pressure-increasing to the self-sustained oscillation in the grooved channels is explored experimentally. The most important results are concluded as follows:

(1) The self-sustained oscillation, appearing in the later period, is sensitive to the pressure-increasing operation. There is an effective range when +Q=10~60ml/s.

(2) The optimum value of pressure-increasing varies with the flow rate of self-sustained oscillation. The relationship between them approximately displays a linear form.

(3) There exists a close relationship between the effect of pressure-increasing and the Reynolds number. The efficient influence of pressure-increasing on the internal pressure exists in the lower flow rate, i.e., Re<1000.

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