Optimum Values of Pressure-increasing for Self-sustained Oscillation in the grooved channel

Yongning BIAN[1], Hirofumi ARIMA[2], Yasuyuki IKEGAMI[2], Faming SUN[1]
[1]State Key Laboratory of Structural Analysis for Industrial Equipment
Dalian University of Technology, 116024, China
[2]Institute of Ocean Energy, Saga University, 840-8502, Japan

Abstract

The optimum values of pressure-increasing for self-sustained oscillations in the grooved channels are investigated experimentally. Time-various local pressures are measured under different pressure-increasing conditions with the pressure sensor. The local pressure signal shows that there exists an effective range for increasing pressure, and with the increment of the inner pressure in the grooved channel, the self-sustained oscillation will appear in the higher flow rate, contrast to the case of no pressure-increasing. It is found that the optimum values of pressure-increasing are different each other for the oscillatory flow with different flow rate. This behavior is very significant for the operation of the efficient heat exchanger in practical engineering.

Key Words: Optimum value; Increasing or decreasing pressure; Self-sustained oscillation; Grooved channel

1. INTRODUCTION

It is 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.

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. Based on the previous results, the strength characteristics of self-sustained oscillations in the grooved channel are carried out[6], and the effect of the pressure-increasing operation on the amplitude of the self-sustained oscillation is found. 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 would be obtained. This prediction will be very significant for the practical enhancement operation of the plate heat exchanger.

In this study, the optimum value will be detected experimentally and more nature behavior will be cleared.

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 measured with an electro-magnetic flowmeter; Q re- presents the flow rate. Five pressure sensors are used to measure the local time-various pressure. The valve-1 and valve-2, 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.

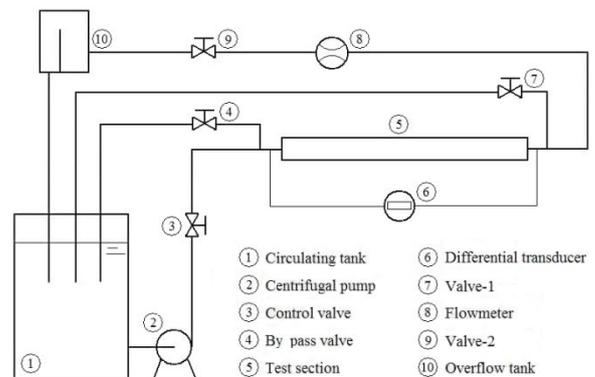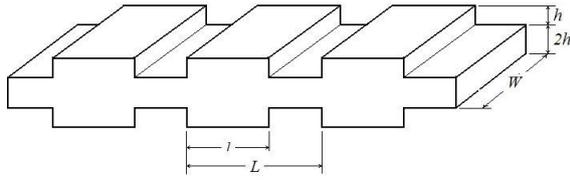|	
① Circulating tank	⑥ Differential transducer
② Centrifugal pump	⑦ Valve-1
③ Control valve	⑧ Flowmeter
④ By pass valve	⑨ Valve-2
⑤ Test section	⑩ Overflow tank

Fig. 1 Schematic diagram of the experimental system

Fig. 2 Dimensions of the test section

The dimensions of the test section are shown in Fig.2. Only one kind of grooved channel, with the period length L=20mm, W=200mm, h=2.5mm and the grooved lengths l=10mm, is 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.

3. RESULTS AND DISCUSSION

3.1 Self-sustained oscillation

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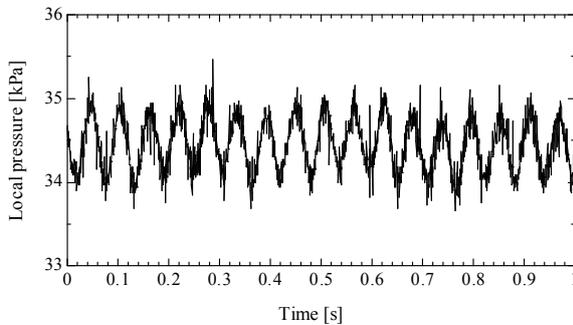
sensor. Obviously, it is easy to detect the oscillation in this way. With a mathematical process, the amplitudes of self-sustained oscillation in whole flow regime are obtained, as showed in Fig. 4. It is sure that the self-sustained oscillation mainly appears in the regime Q=280~360ml/s with no pressure-increasing.

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 late period of the self-sustained oscillation, Fig.5 shows this phenomenon clearly. Moreover, the amplitudes sensitive to the pressure-increasing 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.
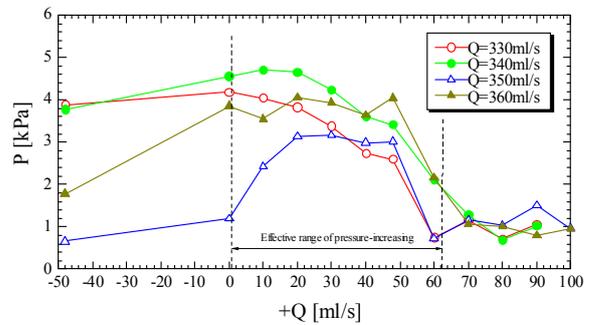

Fig. 3 Self-sustained oscillation at Q=340ml/s

Fig. 5 Sensitive range to pressure-increasing

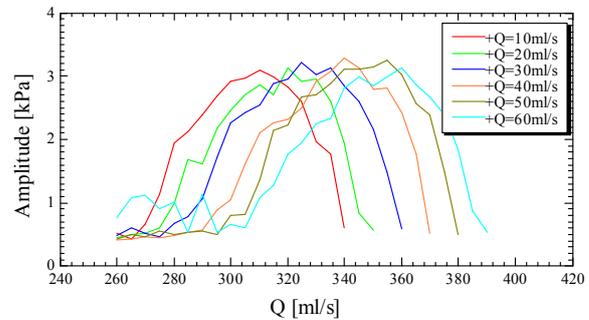Fig. 4 Amplitude of self-sustained oscillation for whole flow retime

Fig. 6 Relationship between the amplitude and the flow rate

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. Corresponds to the flow rate, the relationships between the amplitude and the pressure-increasing value are showed in Fig.7~12. It could be seen clearly that there is an optimum value of pressure-increasing for different operating condition. Table 1 lists the optimum value of pressure-increasing vs. 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.13, 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.
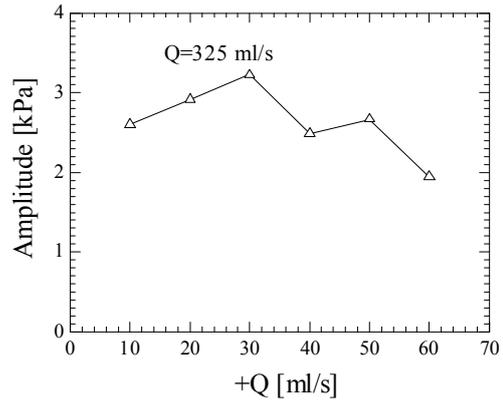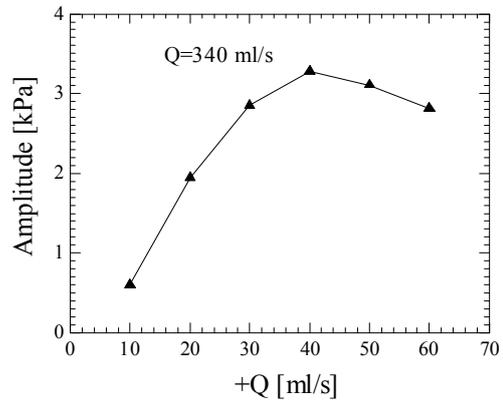

Fig.9 Amplitude vs. +Q at Q=325ml/s

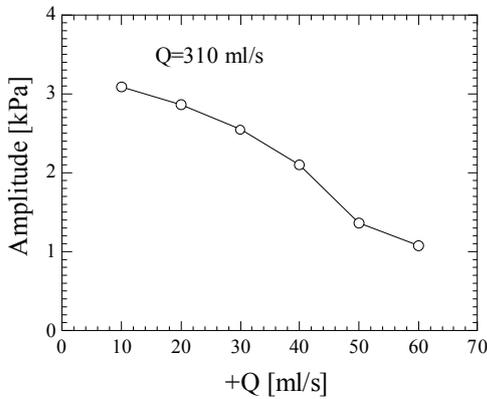Fig.10 Amplitude vs. +Q at Q=340ml/s
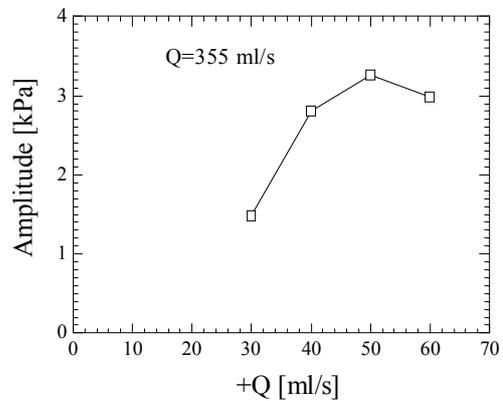

Fig.11 Amplitude vs. +Q at Q=355ml/s

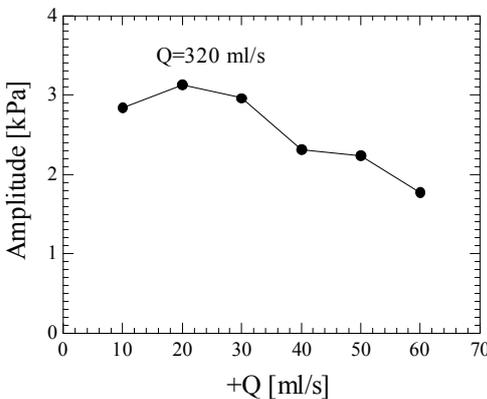Fig.12 Amplitude vs. +Q at Q=360ml/s
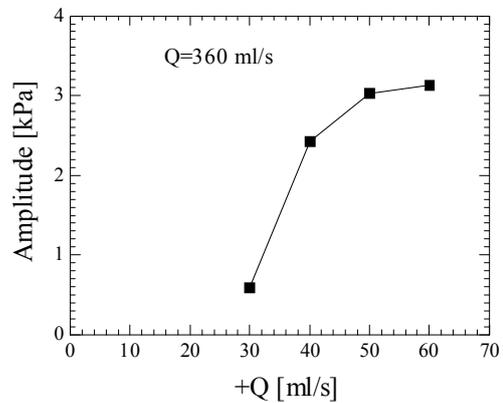

Fig. 7 Amplitude vs. +Q at Q=310ml/s

Fig. 8 Amplitude vs. +Q at Q=320ml/s

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

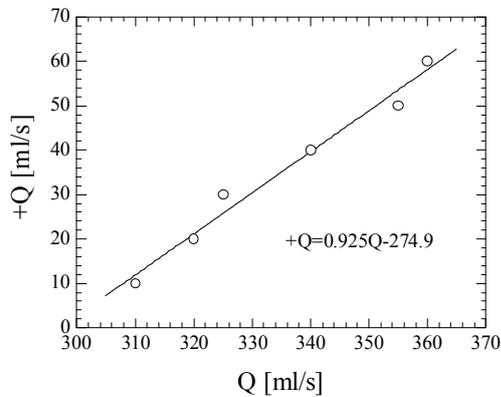| Q(ml/s)	310	320	325	340	355	360
+Q(ml/s)	10	20	30	40	50	60

Fig. 13 +Q vs. Q

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 late 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.

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