Effect of Groove Length on Fluid Flow in Grooved Channels for Pulsatile Flow

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Effect of groove lengths on fluid flow in series grooved channels for pulsatile flow has been conducted experimentally. Mainly, the behaviors of the time-averaged local pressure and the overall pressure drop in all channels are examined. Meanwhile, the amplitudes of the recorded signals are also analyzed. The results showed that the local pressure and the overall pressure drop change significantly with the groove length, but they display the similar tendency for the different pulsatile periods. The present study provides a useful reference to the design of plate-heat exchanger.

Key Words : Groove Length, Fluid Flow, Pulsatile Flow, Local Pressure, Overall Pressure Drop

1. Introduction

Heat transfer enhancement, especially in the plate heat exchangers, could be realized by means of changing the wall shape of the employed channels, it is very important for the ocean thermal energy conversion system to raise the efficiency of power generation. The pulsatile flow, which is formed by imposed an oscillatory flow to the steady flow, is proved to be another effective method to enhance the fluid mixing. The combination of the above two means have already become a new enhancement approach for heat and mass transfer equipment.

Many investigators devoted their efforts to study the mechanical properties of channels with different shapes. Nishimura et al.(1~3) conducted the study on fluid flow and mass transfer characteristics in wavy-walled channels for steady flow. They pointed out that the mainstream passes the central part of the channel and the stable circulating vortex forms at the maximum cross section in laminar flow regime; as the Reynolds number increases further, the vortex will grow and its center will shift to the down stream; when the Reynolds number exceeds its critical value Re_c, the flow instability takes the form of the Tollmien-Schlichting (T-S) wave, and will result in a self-sustained oscillation with a certain frequency. Hyun and Sang(4) described experimentally and numerically the heat and mass transfer characteristics as well as the flow features in a two dimensional rectangular wavy duct with various corrugation angles. As the corrugation angle decreases, the region of flow stagnation at the front part of the pressure wall becomes much wider and the position of flow reattachment on the suction wall moves to the upstream. A higher heat transfer rate appears at the front part of the pressure and suction wall due to main flow impingement and flow reattachment, respectively. Therefore, flow transition to turbulent flow will occur much earlier. Moreover, Wang and Vanka(5) presented detailed results on T-S wave and pointed out that the T-S wave prompts the heat transfer in the wavy-walled channel. Nishimura et al.(6) conducted the study numerically and experimentally in the grooved channel, they also proved that the flow instability is closely related to the heat and mass transfer enhancement in the wavy-walled channel. Bian et al.(7) proposed a novel experimental method for finding the T-S wave by recording the time-various signal of local pressure, it is very useful for the study on heat and mass transfer in the two-dimensional channels. Recently, Bian et al.(8) also examined the pulsatile flow behavior in the grooved channel with the groove length l=12mm, and pointed out that the maximum oscillatory fraction could be reached at 0.28 for Q=200ml/s and T=2.4s. This result provides an important reference for the present study.

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In this study, the time-varied local pressure and overall pressure drop are measured in series grooved channel with different groove length for pulsatile flow. With the time-averaged treatment to the data, the effects of groove length on the fluid flow are described clearly.

2. Experimental Setup

The experiments are carried out with the same apparatus as before[8], as showed in Fig.1. 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. Considering the effects of the entrance length, all of experimental data are captured from the downstream in the grooved channel. All the experiments are conducted under the condition Q=200ml/s, *on*=*off* =0.1~1.2s. All the parameters used here are identical to the reference[8].

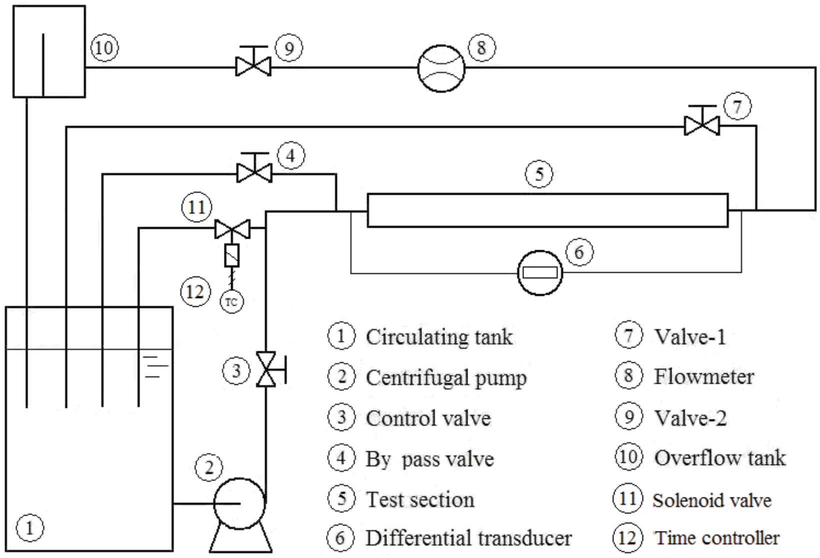
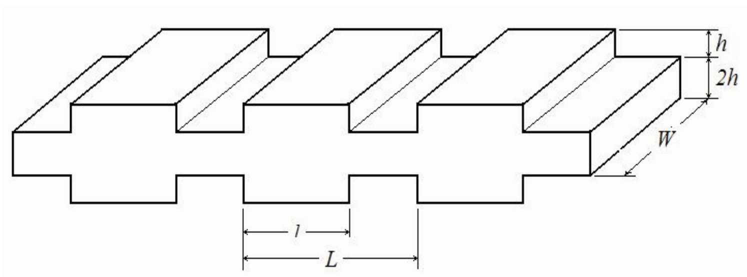


Fig. 1 Sketch of experimental system



L=20mm, W=200mm, h=2.5mm and l=4,6,8,10,12,14mm

Fig. 2 Dimension of grooved channel

3. Results and Discussion

3.1 Time-varied signals of local pressure and overall pressure drop

In the present experimental system, the pulsatile flow are generated by the solenoid valve with different pulsatile periods in the grooved channels with l=4~14mm, which is realized by adjusted the on and off time. The representative time-varied pulsatile signals of the flow rate, the local pressure $P7$(7 means the setting location of the pressure sensor) and the overall pressure drop dP are displayed in Fig. 3. For this case, the oscillatory fraction is very small, only is 0.052. The results showed that when the flow starts to oscillate, the dP will be triggered the

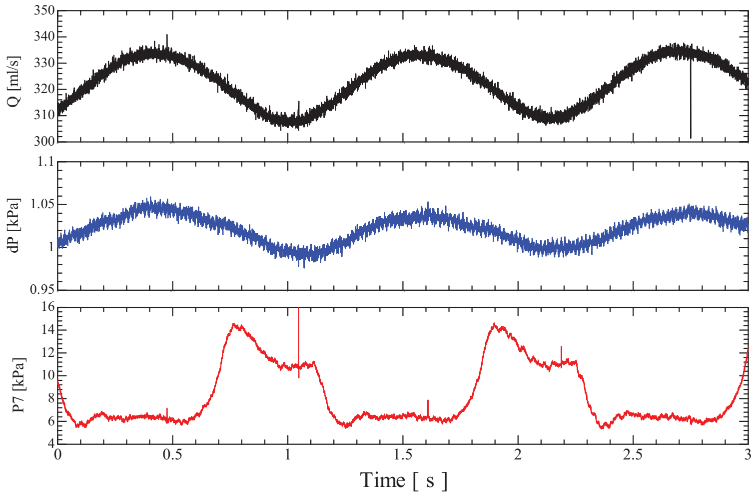


Fig. 3 Representative pulsatile flow signals

same behavior with the zero phase shift. Meanwhile, the *P7* displays a different behavior, that is, *P7* changes in an opposite trend with a little phase shift during the periods of the pulsatile flow rate increasing and decreasing. It has been already proved that the pulsatile flow will promote the motion of the flow vortex and the fluid mixing[9], thus will enhance the heat and mass transfer in the flow channel.

3.2 Effect of groove length on the local pressure

Based on the time-history data for the pulsatile flow, the time-averaged behaviors of the local pressure and the overall pressure drop with different pulsatile period are analyzed. After finished the data treatment, the results for *on=off* =0.5,0.7 and 1.2s are used to illustrated the effect of groove length on the fluid flow. Fig. 4 showed the relationship between the groove length l and the local pressure P. It is seen that with the increment of l, there have a maximum value for *P* at *l*=10mm. Generally, the larger the *P* is, the stronger the vorticity is. It implies that the strength of fluid mixing in the grooved channel with *l*=10mm is better than the other ones.

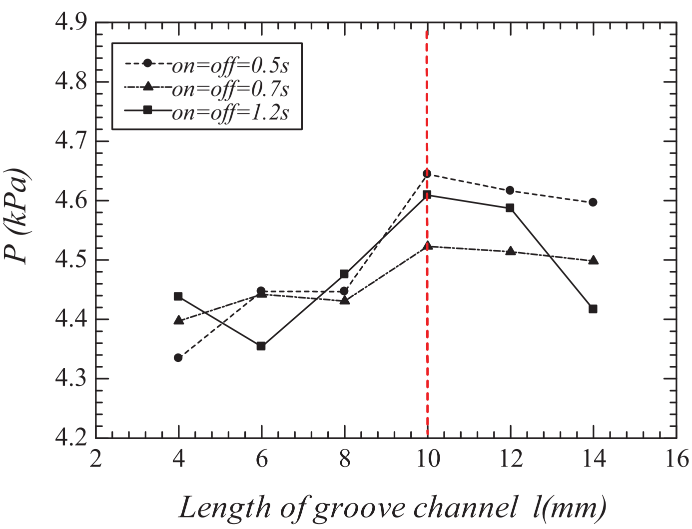


Fig. 4 Available experimental operating range

To further insight the effect of the groove length, the averaged amplitude of the local pressure for pulsatile flow A-P is calculated. The result is displayed in Fig. 5. For the three pulsatile periods, the amplitudes change with the groove length in the similar trends. In all of six kinds of channels, the minimum amplitude fluctuation occurs in the channel l=10mm, it means that this channel has the best stability for the fluid flow.

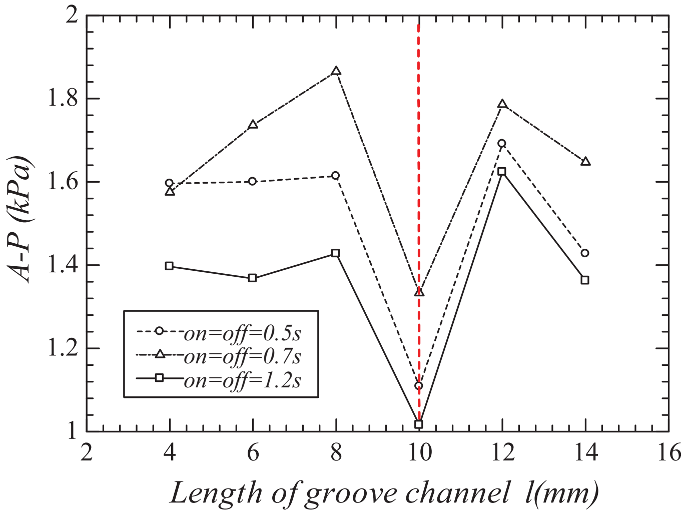


Fig. 5 Relationships between the groove length and the amplitude of the local pressure

3.3 Effect of groove length on the overall pressure drop

The overall pressure drop is an important index to evaluate the performance of the fluid equipment. With the aforementioned method of data processing and analysis, we examined the effect of groove length on the overall pressure drop, as showed in Fig. 6. This figure indicated that the pressure drop will increase when *l* is small or larger. In this study, the middle level pressure drop just exists in the grooved channel with *l*=10mm. Furthermore, the effect of pulsatile period on *dP* are different from it on the local *P*, the varied tendency of *dP* are almost identical in all of six kinds grooved channels.

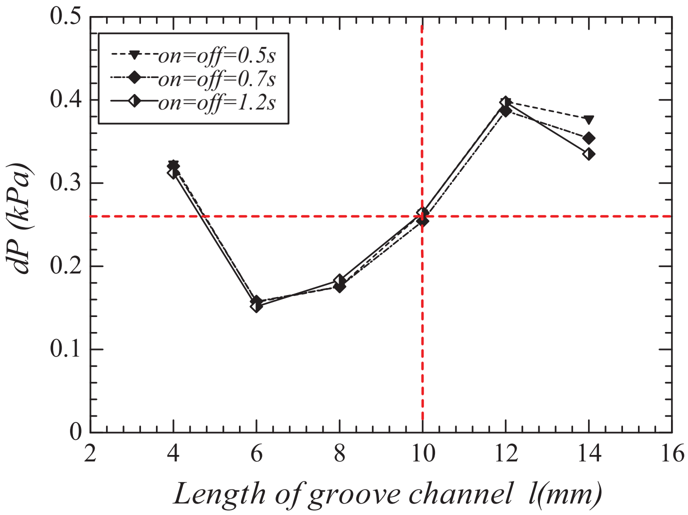


Fig. 6 Effect of grooved length on overall pressure drop

Similarly, the averaged amplitudes of overall pressure drop for pulsatile flow *A-dP* are drawn in Fig. 7 for all grooved channels. Obviously, unlike the results showed in Fig.4~6, the *A-dP* changes relatively flat with *l*, but when *l*=10mm, the *dP* amplitudes still display a small value, showed a good hydrodynamic stability.

To sum up the above experimental analysis result, whatever starting from the viewpoint of the local pressure or the overall pressure drop, the channel with groove length *l*=10mm is a good choice, and its hydrodynamic performance is superior to the other grooved channels.

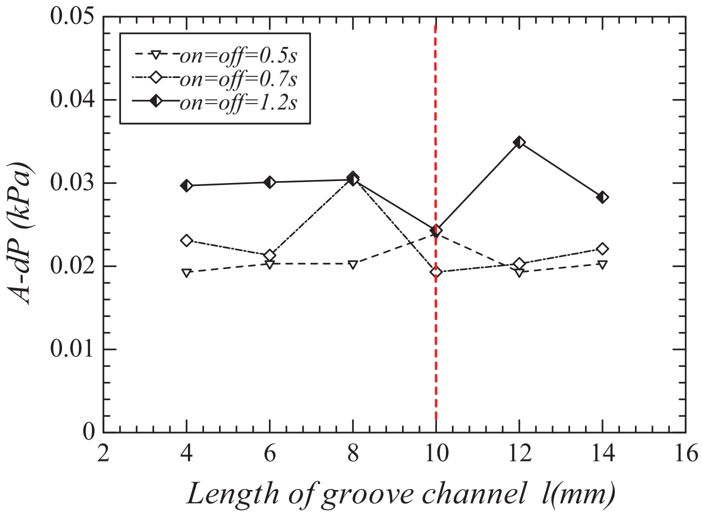


Fig. 7 Relationships between the groove length and the amplitude of the overall pressure drop

4. Conclusions

In this study, the effect of groove length on the local pressure and the overall pressure drop was explored experimentally. Some important results were proposed as follows:

(1) The local pressure will change with the groove length, and there exists a maximum value corresponded to the channel l=10mm, means the strength of fluid mixing in this channel is better than that in the other ones. Meanwhile, the best stability for the fluid flow could be obtained in this channel.

(2) The overall pressure drop is higher at small or large l, the middle level overall pressure drop exists in the grooved channel with l=10mm. For the different pulsatile periods, the varied tendency of dP are almost identical in all of six kinds grooved channels.

(3) Based on the experimental data processing and analysis, it could be realized that the channel with groove length l=10mm is a good choice, and its hydrodynamic performance is superior to the other grooved channels.

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