Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

A numerical investigation of the flow of nanofluids through a micro Tesla valve

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Cite this as: Jin-yuan QIAN, Min-rui CHEN, Xue-ling LIU, Zhi-jiang JIN, 2019. A numerical investigation of the flow of nanofluids through a micro Tesla valve. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 20(1):50-60.

https://doi.org/10.1631/jzus.A1800431

T45-R Tesla valve

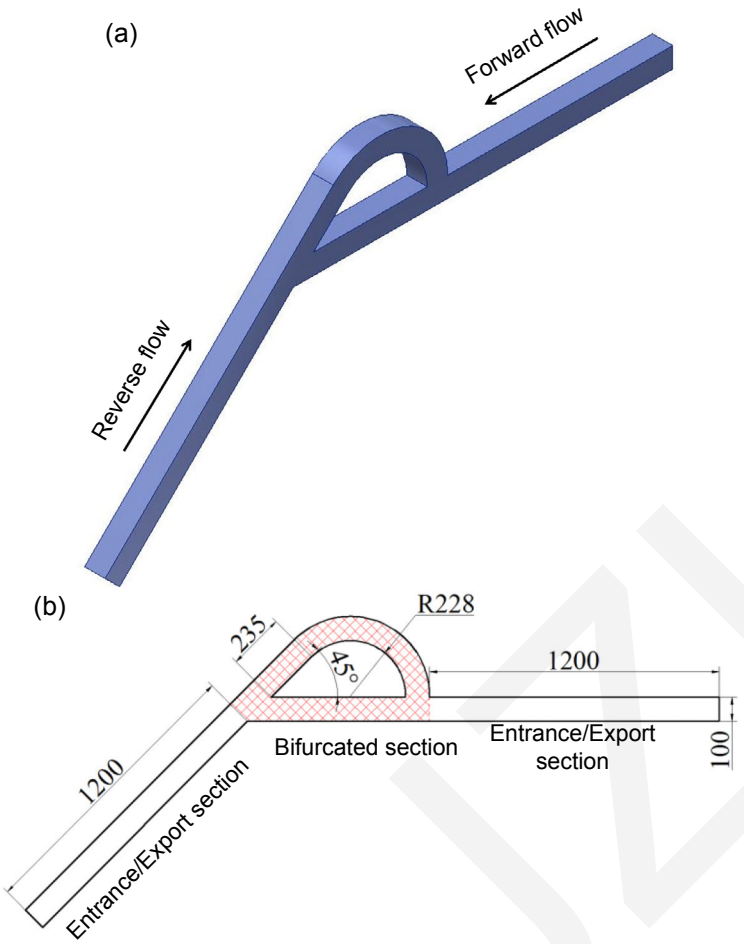


Fig. 1 Geometric model of a T45-R Tesla valve
(a) 3D model of a T45-R type Tesla valve; (b)Geometric parameters of the micro-scale T45-R type Tesla valve (unit: μm)

The Tesla valve is a passive valve without valve core. It consists of three parts, including entrance section, bifurcated section and export section. When fluids flow through a Tesla valve forward, the pressure drop is less than flow reversely, so that the Tesla valve can control the flowing direction. In the present study, the T45-R Tesla valve is investigated.

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Effects of nanofluids flow rate

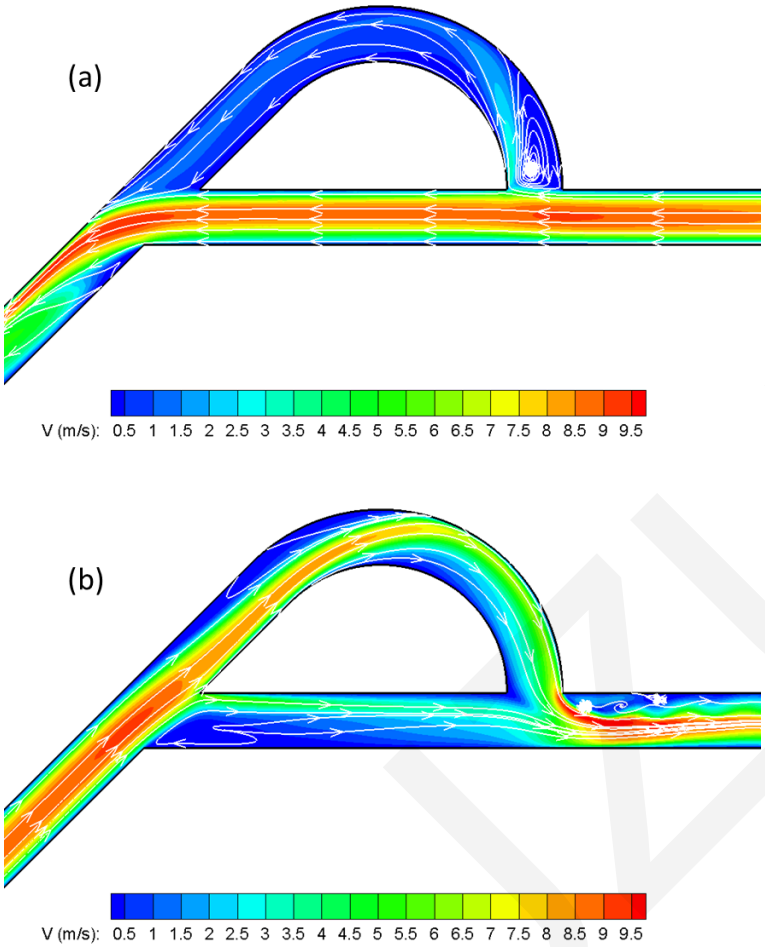


Fig. 2 Velocity contours with a flow rate of 3 mL/min
(a) Forward flow; (b) Reverse flow

The nanofluids separated at the bifurcation section for both flow directions. When flowing forward through the micro-scale T-45R type Tesla valve, the nanofluids flow mainly into the straight channel. In contrast, when the nanofluids flow reversely through the Tesla valve, most of them flow into the arc channel.

Effects of nanofluids flow rate

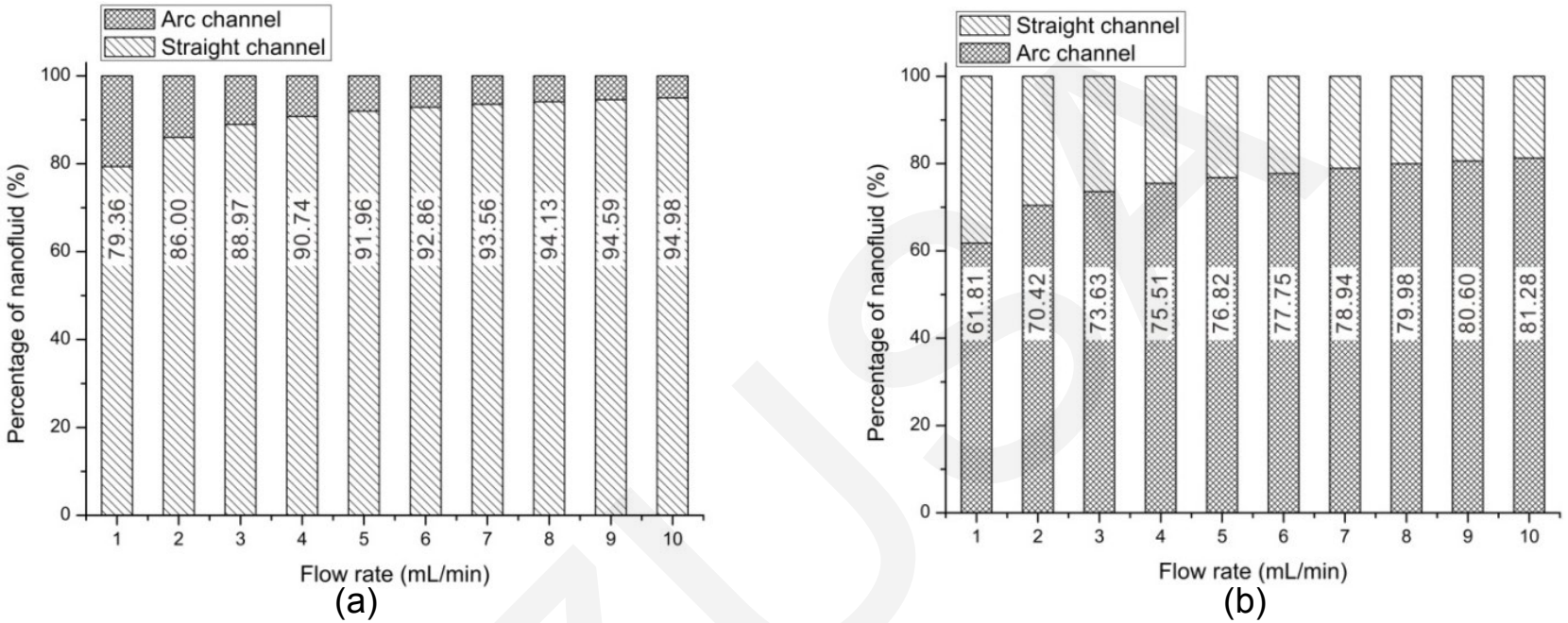


Fig. 3 Percentage of flow in the bifurcated section with different flow rates
(a) Forward flow; (b) Reverse flow

With the nanofluids flow rate increasing, the percentage of flow entering the straight channel in the forward direction and the percentage of flow entering the arc channel in the reverse direction both increase. The effect of flow rate on the nanofluids flow separation will be increasingly marginal when the flow rate is large enough.

Effects of nanofluids flow rate

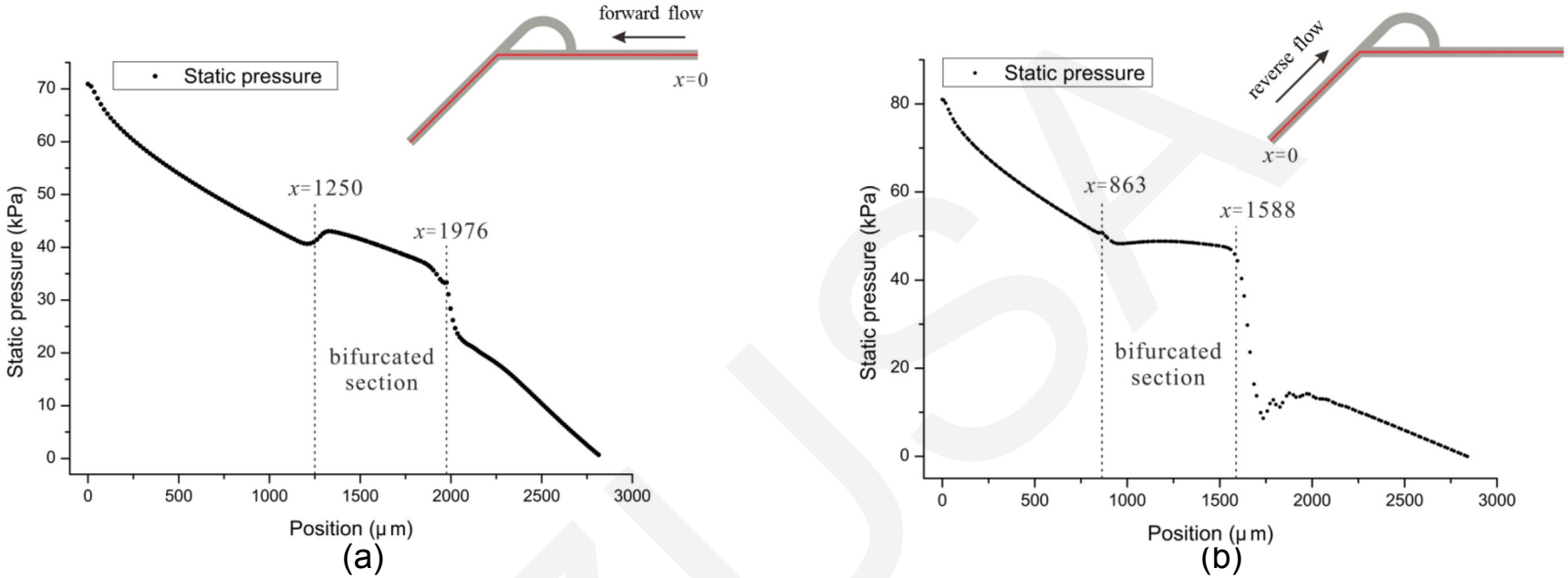


Fig. 4 Static pressure along the center line of the micro-scale T-45R type Tesla valve with a flow rate of 3 mL/min

(a) Forward flow; (b) Reverse flow

For both flow direction, the static pressure along the center line of the micro-scale T-45R type Tesla valve changes near the bifurcated section. In the reverse flow, due to the jet flow from the arc channel, the static pressure at the center line decreases dramatically, especially at the export of the bifurcated section.

Effects of nanofluids flow rate

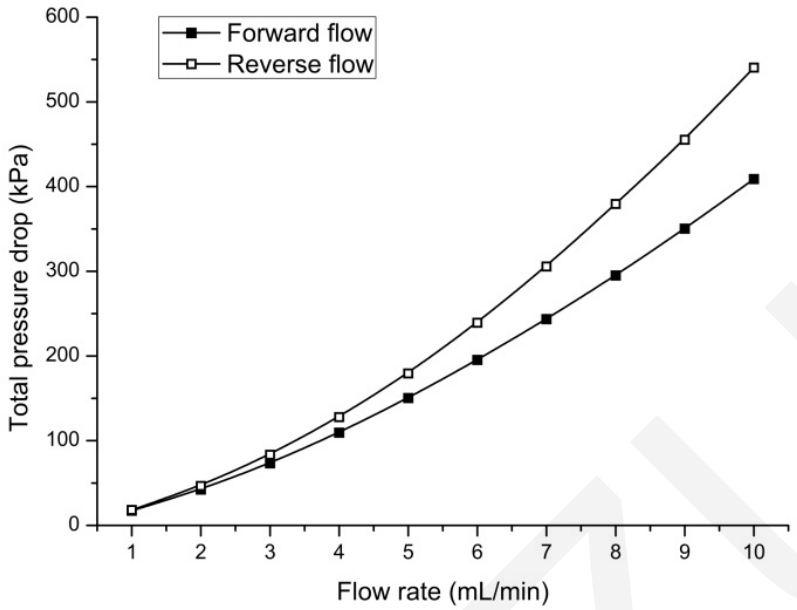


Fig. 5 Forward and reverse pressure drop with different flow rates

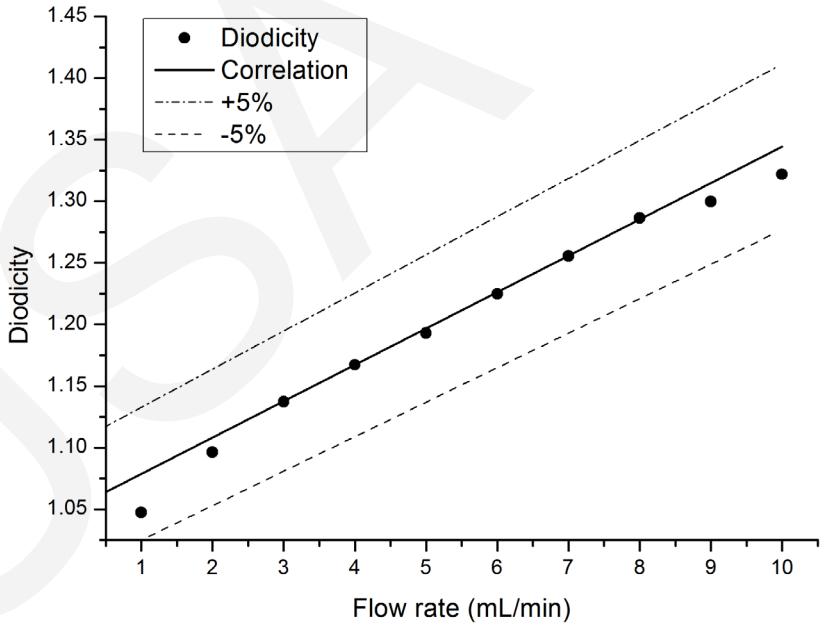


Fig. 6 Change in diodicity with flow rate

The reverse pressure drop increases more drastically than the forward pressure drop. The diodicity increases with the flow rate, following the correlation $Di=0.0295F+1.0493$

Effects of nanofluids temperature

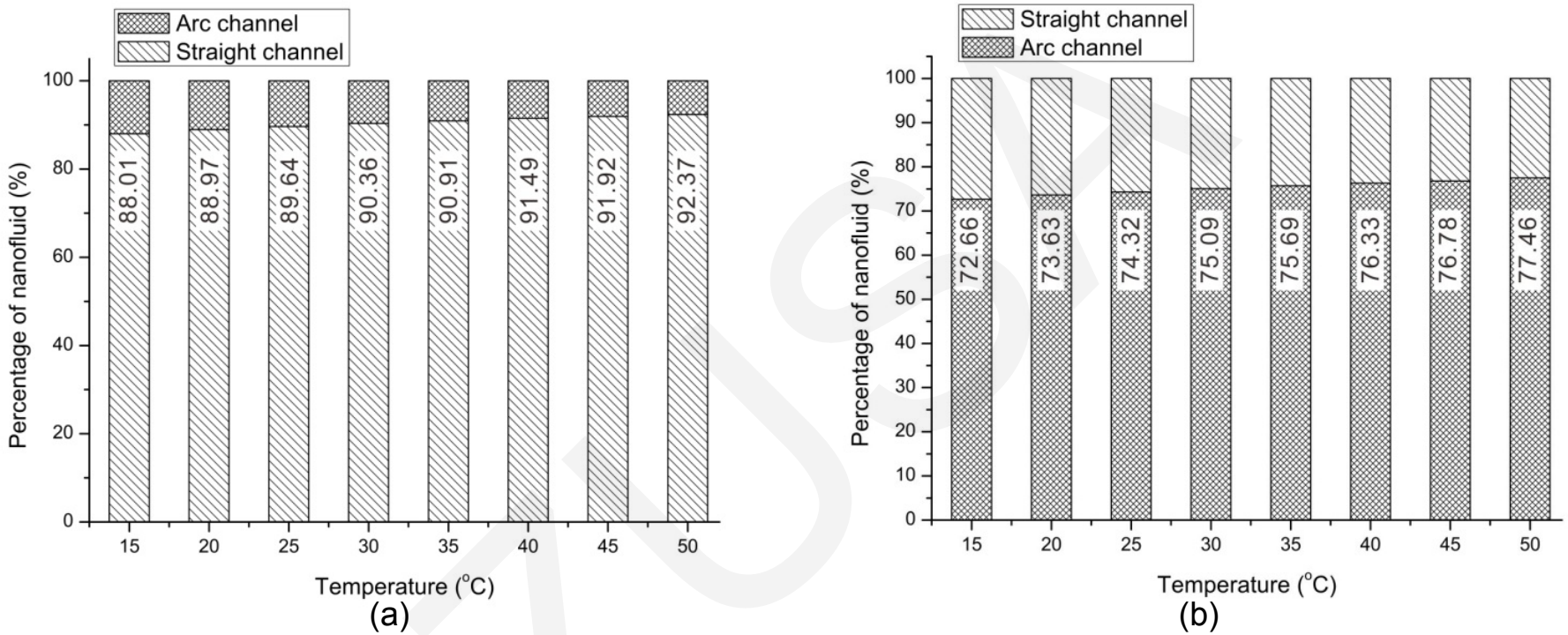


Fig. 7 Percentage of flow in the bifurcated section at different temperatures
(a) Forward flow; (b) Reverse flow

With the nanofluids temperature increasing, the percentage of flow entering the straight channel in the forward direction and the percentage of flow entering the arc channel in the reverse direction both increase, and the increase becomes more gradual as the temperature increases.

Effects of nanofluids temperature

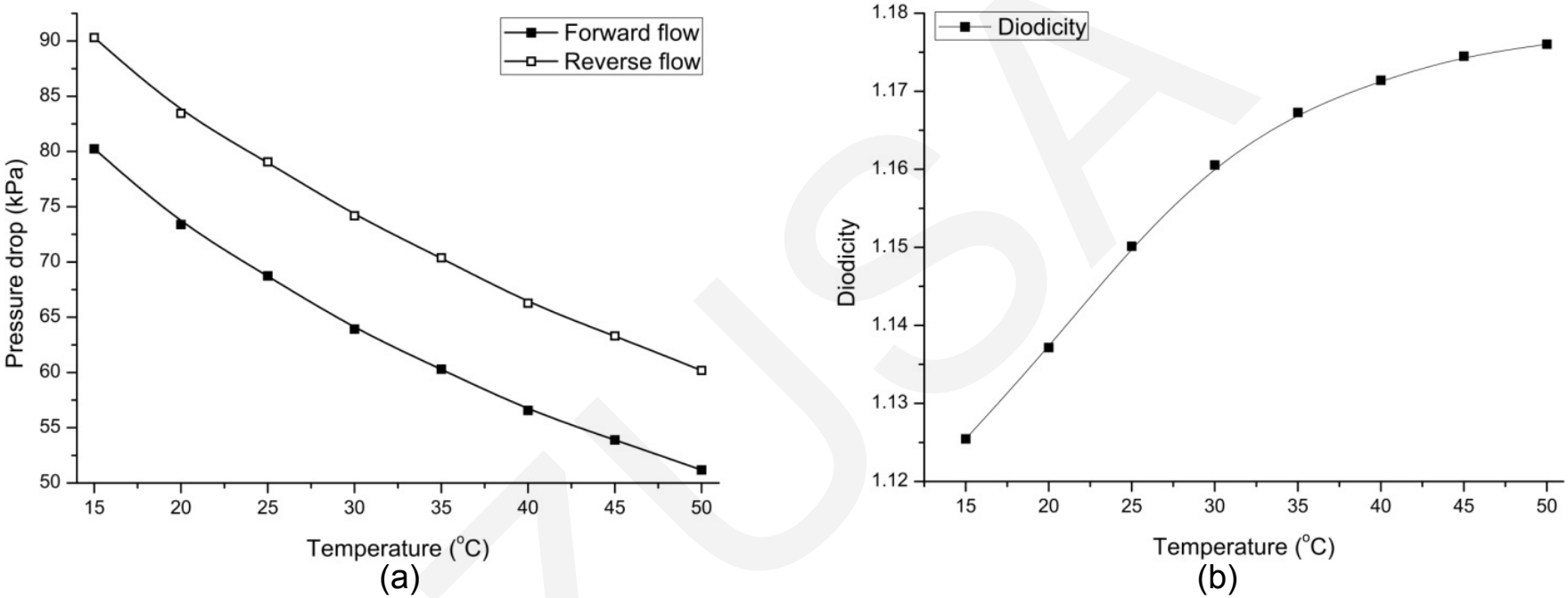


Fig. 8 Pressure drop characteristics at different temperatures
(a) forward flow and reverse flow pressure drop; (b) diodicity

For both flow directions the pressure drop decreases as the temperature increases. Diodicity increases with temperature and the increasing trend is more drastic at lower temperatures.

Effects of nanoparticle volume fraction

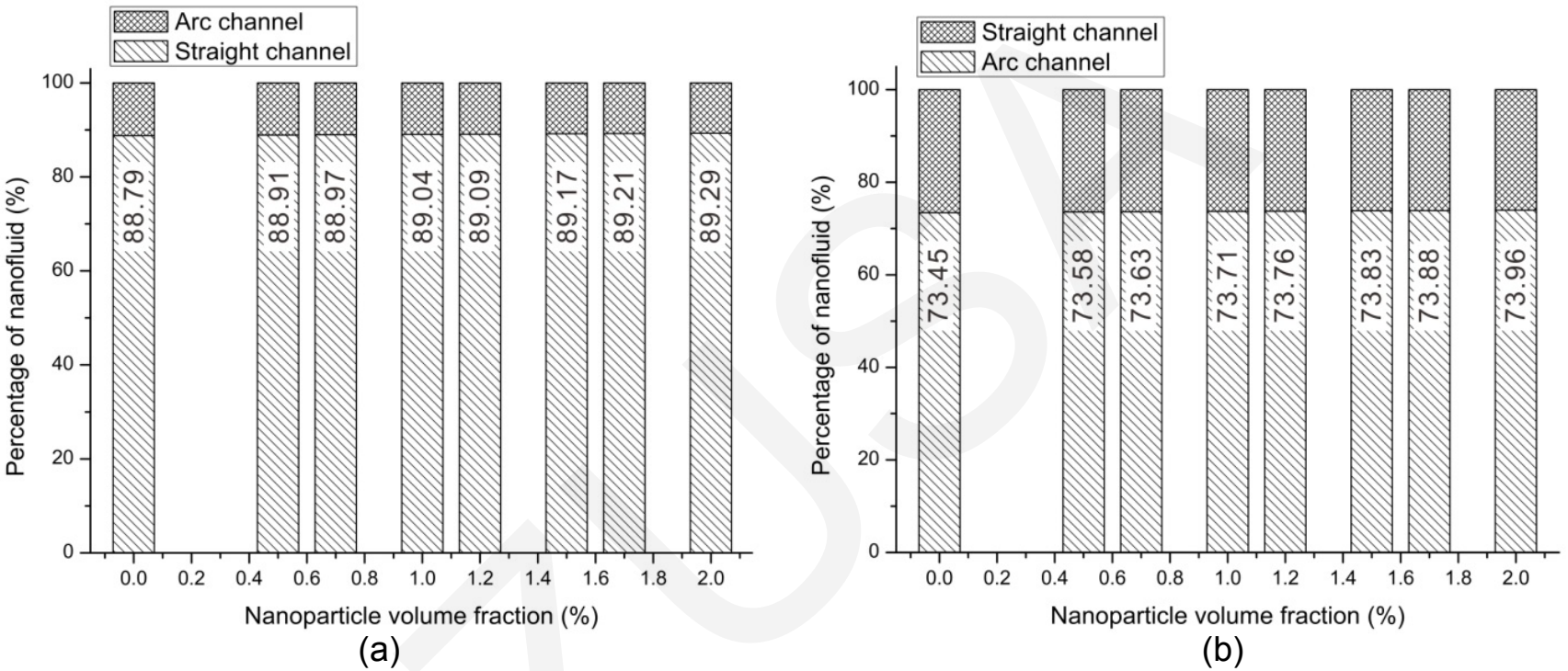


Fig. 9 Percentage of flow in the bifurcated section with different nanoparticle volume fractions
(a) Forward flow; (b) Reverse flow

The effect of nanoparticle volume fraction on the separation of nanofluid in the bifurcated section is not large, which can be ignored.

Effects of nanoparticle volume fraction

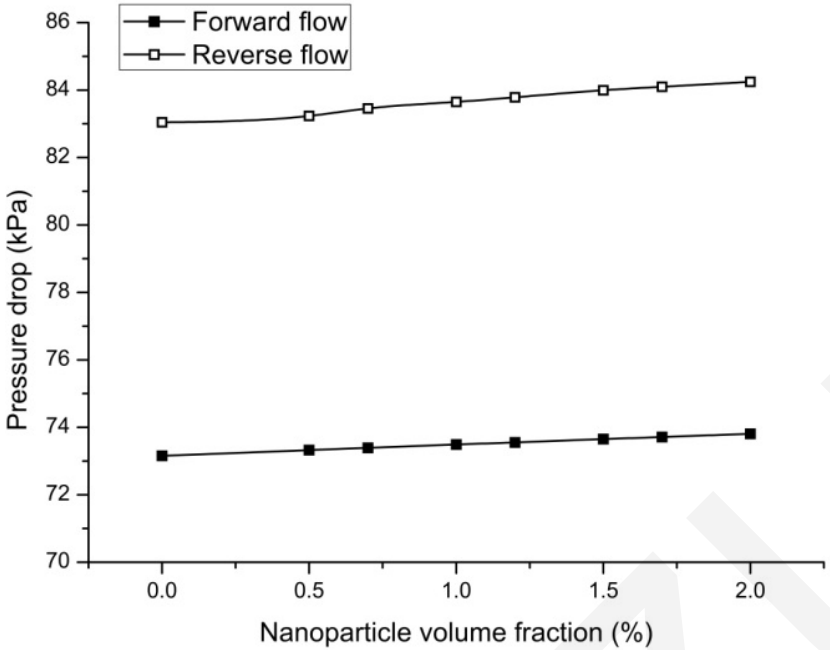


Fig. 10 Forward flow and reverse flow pressure drop with different nanoparticle volume fractions

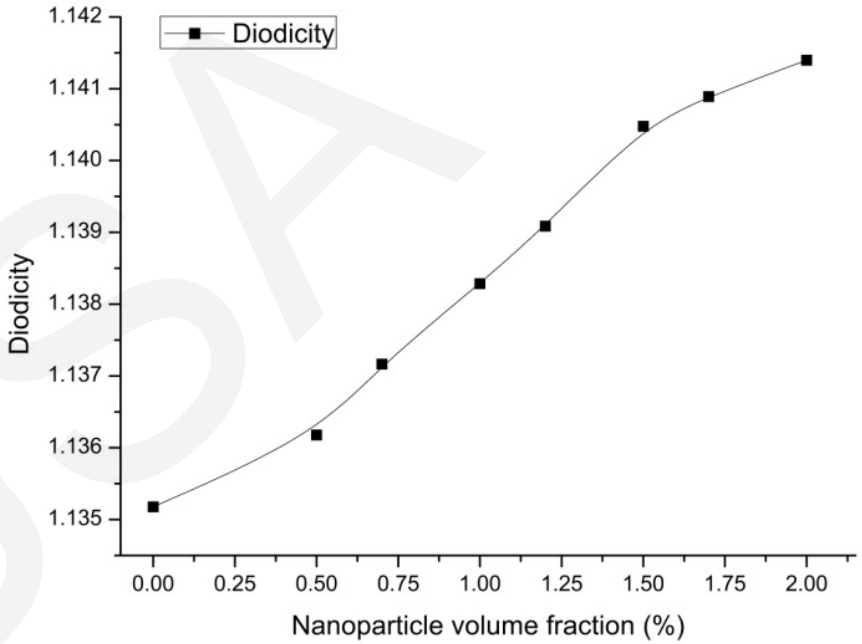


Fig. 11 Diodicity with different nanoparticle volume frac-tions

For both flow directions, the pressure drop increases with the nanoparticle volume fraction, though the increase is minor

Diodicity increases with increasing nanoparticle volume fraction, and the increase in diodicity declines when the nanoparticle volume fraction is above 1.5%.

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Conclusions

- Most of the nanofluid flows into the straight channel of the bifurcated section when flowing forward, and into the arc channel when flowing reversely.
- The percentage of the main flow increases with increasing flow rate, temperature and nanoparticle volume fraction, despite its limited effect.
- When the nanofluid flows through the Tesla valve reversely, the jet flow from the arc channel influences the pressure drop significantly, leading to a larger pressure drop than forward flow.
- Diodicity was most affected by the flow rate. In the range of this study, the diodicity changed almost linearly with the flow rate, and a correlation for calculating the diodicity has been proposed.