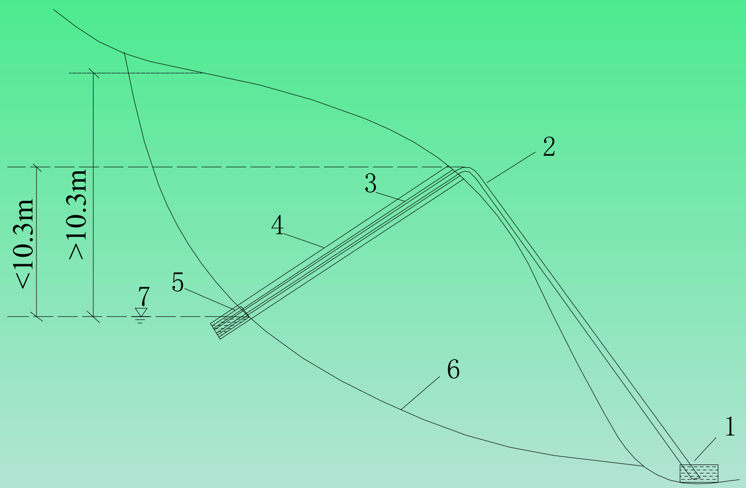
High-lift siphon flow velocity in a 4-mm siphon hose

Cheng MEI, Xu LIANG, Hong-yue SUN, Meng-ping WU

Key words: Siphon flow velocity, High-lift siphon, Elevation difference, Water lift, Gas effect

Cite this as: Cheng Mei, Xu Liang, Hong-yue Sun, Meng-ping Wu, 2017. High-lift siphon flow velocity in a 4-mm siphon hose. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 18(6):487-495. http://dx.doi.org/10.1631/jzus.A1600428

Backgrounds and Test Model



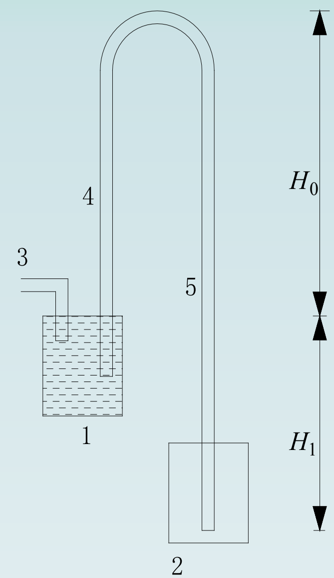
1: outlet; 2: siphon hoses; 3: PVC pipe; 4: inclined borehole; 5: water storage pipe; 6: potential slide surface; 7: underwater level

Fig. 1 Scheme of a practical siphon drainage

Advantages of the 4-mm siphon hoses for slope siphon drainage

- Economical
- Real-time
- Long-term
- Simple construction
- High-lift

Simplified Model



1: Tank A; 2: Tank B; 3: replenished water pipe; 4: upper hose; 5: lower hose

Fig. 2 Schematic diagram of siphon drainage system

Research Priorities

To explore the practical drainage efficiency and capacity of the 4-mm internal diameter siphon hose

Test Data and Analysis

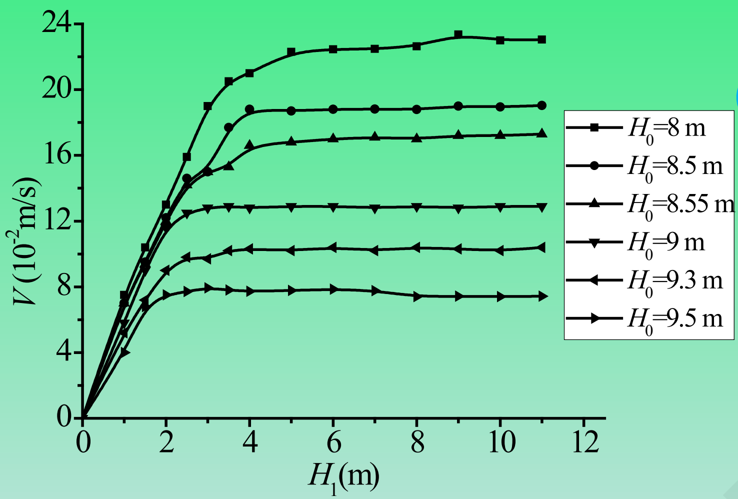


Fig. 4 Siphon flow velocity in a 50-m hose when the water lift is 8.0 m, 8.5 m, 8.55 m, 9.0 m, 9.3 m and 9.5 m, respectively.

Test Data

Observations

Fig. 3 Gas columns in an 8 m water lift (left) and a 9.5 m water lift (right)

Large Deviation

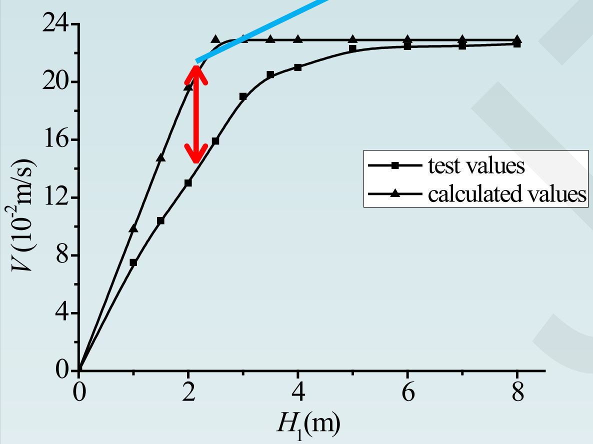


Fig. 5 In an 8 m water lift, the siphon flow velocity varies with H_1

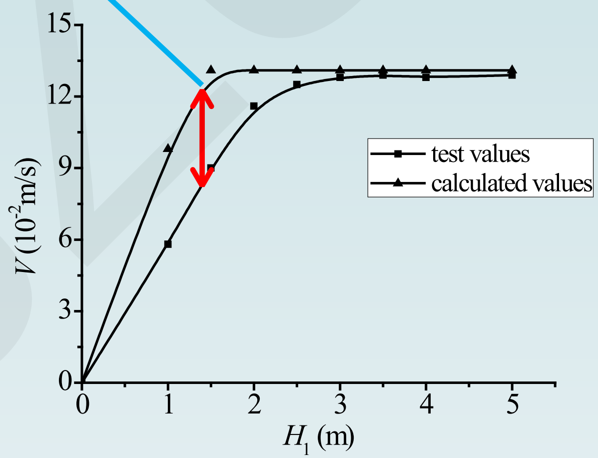


Fig. 6 In a 9 m water lift, the siphon flow velocity varies with H_1

$$V = \sqrt{\frac{2gH}{1+\lambda\frac{L}{d}+\sum\zeta}}$$

Conventional hydraulics formula for the pressurized pipe flow could not really meet the precise calculation required of the high-lift siphon flow velocity.

The hydraulics formula for high-lift siphon flow velocity in a 4-mm siphon hose

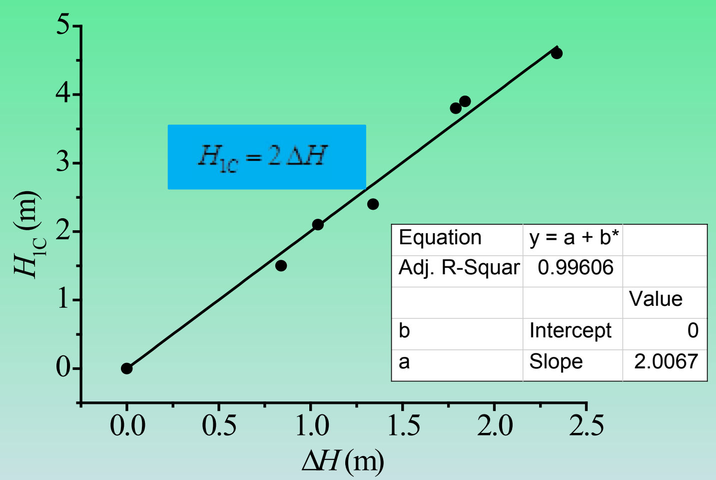


Fig. 6 Fitting relationship between the critical elevation difference H_{1c} and ΔH

The controlling factor of the siphon flow velocity

$H_1 < 2\Delta H$

Add a reduced coefficient α

$$V=\sqrt{\frac{2\alpha g H_1}{1+\lambda\frac{L}{d}+\sum\zeta}}$$

$H_1 \geq 2\Delta H$

$$V_1=\sqrt{\frac{2g\Delta H}{1+\lambda\frac{L}{d}+\sum\zeta}}$$

$\Delta H = H_{max} - H_0$, 8m ≤ H_0 ≤ 10.3m .

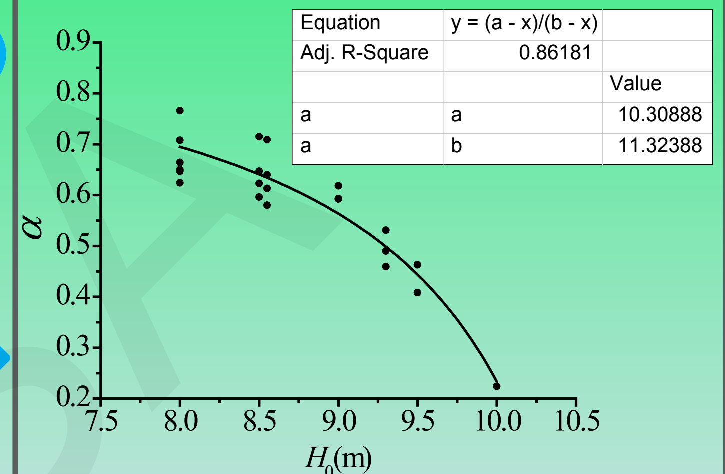


Fig. 7 Fitting relationship between the reduced coefficient α and the water lift H_0

$$\alpha=\frac{10.31-H_0}{11.32-H_0}$$

$$V_2=\sqrt{\frac{2\alpha g H_1}{1+\lambda\frac{L}{d}+\sum\zeta}}$$

$\alpha=\frac{10.31-H_0}{11.32-H_0}$, 8m ≤ H_0 ≤ 10.3m, $V_1 \geq V_2$.

Conclusions

(1) When the elevation difference H_1 remained unchanged, the siphon flow velocity had a negative correlation with the water lift, but when the water lift H_0 was constant, the siphon flow rate accelerated with the increasing elevation difference H_1 until it reached the maximum flow rate and maintained a steady state. The stable flow rate was defined as the critical flow rate, at which the elevation difference H_1 was the critical elevation difference H_{1c}. The siphon flow velocity had a negative correlation with the length of the siphon hose.

(2) In high-lift siphon drainage, the bubbles increased with the decreasing gas pressure and formed a gas-liquid two-phase flow, affecting the calculation of the siphon flow rate. As a result, the current hydraulics formula for pressurized pipe flow proved to be an inappropriate way of measuring the siphon flow velocity in a 4-mm siphon hose.

(3) The high-lift siphon flow velocity in a 4-mm siphon hose under standard atmospheric pressure was controlled by the hose section with the smallest hydraulic gradient. When $H_1 < 2\ \Delta H$, the elevation difference H_1 was the controlling factor for the siphon flow rate. When $H_1 \geq 2\Delta H$, the difference between the maximum limit of the local siphon water lift H_{max} and H_0 was the most important factor. In an engineering setting, it is thus unnecessary to increase the siphon elevation difference blindly; this should approach the critical elevation difference and act as a convenient way of designing a practical siphon.

(4) A direct test is available for related data with respect to high-lift siphon flow velocity in a 4-mm siphon hose. The empirical formula is also a fairly precise way of accessing the siphon flow rate. The calculated values for the siphon flow rate can provide a basis for operational parameters, e.g. the number of siphon hoses and the layout of siphon drainage holes in practical engineering.