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HYDRAULICS OF MICROTUBE EMITTERS IN A DRIP IRRIGATION SYSTEM

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Abstract: Studios were conducted on the hydraulics of microtube emitters in a drip irrigation system. The relationships between the parameters, viz., pressure head H, length L, diameter D and discharge Q were estimated for combined and individual flow conditions, *viz.*, laminar, transition and turbulent, by fitting multiple log-linear regression equations. Minor loss coefficients were obtained and the friction loss equations established. Equations similar to Blasius and general equations were developed for friction factor in turbulent and laminar regions.

Key words: Drip irrigation, hydraulics, microtube emitters

INTRODUCTION

Drip irrigation is one of the recent innovations for applying water to the field and it represents a definite advancement in irrigation technology. Microtube is a simple type of emitter which is attached to the lateral, distributes water for irrigation. It is having an inside diameter of less than 6 mm. Microtubes are easy to install and relatively low in cost compared to other type of emitters. The essential item in the microtube emitter design is the calculation of energy drop caused by a certain flow discharge from the microtube emitter. This energy drop is a combination of minor loss and friction drop. Design information about minor loss has been determined for larger diameter pipes but information is lacking for small microtubes covering the flow regions, viz., laminar, transition and turbulent. There was no empirical equation available for calculating the friction drop from a microtube with an inside diameter ranging from 1 mm to 4 mm. Since both Williams and Hazen equations and the Blasius equation were determined empirically for relatively larger size pipes with turbulent flow, empirical equations were needed for microtubes of a size less than 4 mm and with flow conditions in all the three flow regions. Experiments were conducted to study the hydraulics of microtube emitters, for arriving at suitable empirical equations.

MATERIALS AND METHODS

Black polyethylene tubes of sizes 25 mm and 12.5 mm were used as the main and laterals respectively. The laterals were connected to the main line by Tee joints. In the laterals, holes were drilled to insert microtubes. Microtubes of sizes 1 mm, 2 mm and 3 mm were used. Each microtube was tested under three pressure heads of 50 cm, 100 cm and 150 cm. Three lengths of 50 cm, 100 cm and 150 cm of each size were used. The time taken for collecting a certain volume of water was noted.

RESULTS AND DISCUSSION

In order to identify the flow regime in which flow occurs, the Reynolds number was calculated. The concept of Reynolds number which distinguishes the regimes of laminar and turbulent flow is quite useful in the study of water flow phenomenon. The Reynolds number was calculated using the equation:

$$Re = \frac{VD}{\gamma} \qquad ....(1)$$

where

Re = Reynolds number

V = velocity of flow, m/s

D = diameter of the pipe, m

γ = kinematic viscosity of water at 30°C

= 0.804×10^{-6} m²/s

The relationships between the parameters, viz., pressure head, length, diameter and discharge were estimated for different flow conditions by fitting multiple log-linear regression equations.

Table 1 Hydraulics of microtube emitters

H	L	D	Q	V	Re	H_f	H_m	H_c	f
Turbulent flow									
1.5	50	3	54.50	2.140	7985	1.00	0.50	1.50	0.026
1.0	50	3	44.00	1.729	6451	0.69	0.33	1.02	0.027
1.5	100	3	40.39	1.587	5922	1.18	0.27	1.45	0.027
1.5	150	3	34.20	1.344	5015	1.33	0.20	1.53	0.029
1.0	100	3	32.73	1.290	4813	0.82	0.18	1.00	0.029
0.5	50	3	29.80	1.711	4369	0.35	0.15	0.50	0.030
1.5	50	2	19.58	1.731	4306	1.17	0.33	1.50	0.031
Flow in transition region									
1.0	150	3	22.30	0.876	3269	0.91	0.12	1.03	0.047
1.0	50	7.	14.40	1.273	3167	0.73	0.26	0.99	0.035
1.5	100	2	12.88	1.140	2836	1.25	0.21	1.46	0.038
0.5	100	3	17.01	0.668	2493	0.41	0.07	0.48	0.054
1.5	150	2	10.40	0.919	2286	1.37	0.14	1.51	0.042
1.0	100	2	10.11	0.894	2225	0.87	0.13	1.00	0.043
0.5	50	2	9.47	0.837	2082	0.40	0.11	0.51	0.045
Laminar flow									
0.5	150	3	12.74	0.501	1869	0.49	0.010	0.50	0.077
1.0	150	2	6.82	0.603	1500	0.98	0.020	1.00	0.071
1.5	50	1	3.05	1.078	1340	1.46	0.003	1.46	0.049
0.5	100	2	5.40	0.477	1188	0.49	0.009	0.50	0.085
1.0	50	1	2.20	0.778	968	0.98	0.026	1.01	0.064
0.5	150	2	3.92	0.347	863	0.50	0.005	0.51	0.109
1.5	100	1	1.75	0.619	770	1.48	0.016	1.50	0.096
1.5	150	1	1.27	0.449	558	1.49	0.009	1.50	0.097
1.0	100	1	1.27	0.449	558	1.00	0.009	1.01	0.097
0.5	50	1	1.25	0.442	550	0.49	0.008	0.50	0.098
1.0	150	1	0.91	0.318	396	0.99	0.004	0.99	0.128
0.5	100	1	0.72	0.255	317	0.50	0.003	0.50	0.151
0.5	150	1	0.52	0.184	229	0.50	0.001	0.50	0.193

H = Pressure head (m), L = Length (cm), D = Diameter (mm), Q = Discharge (l/h), V = Velocity (m/s), Re = Reynolds number, Hf = Friction loss (m), 1 I_m = Minor loss (m), H_c = Computed pressure head (m) and f = friction factor

With the help of a computer, the above analysis was made for combined flow conditions and for each individual flow condition, viz., laminar, transition and turbulent. The empirical equations obtained were as follows:

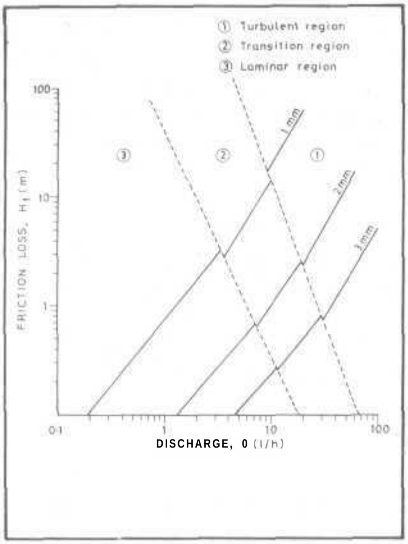

Fig.1 Discharge-friction loss relationship based on various flow conditions

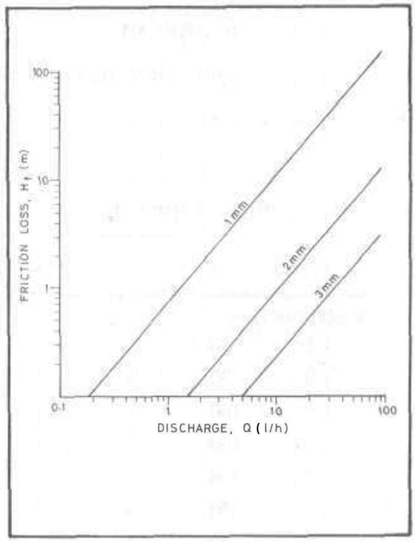

Fig.2 Discharge-friction loss relationship for combined flow condition

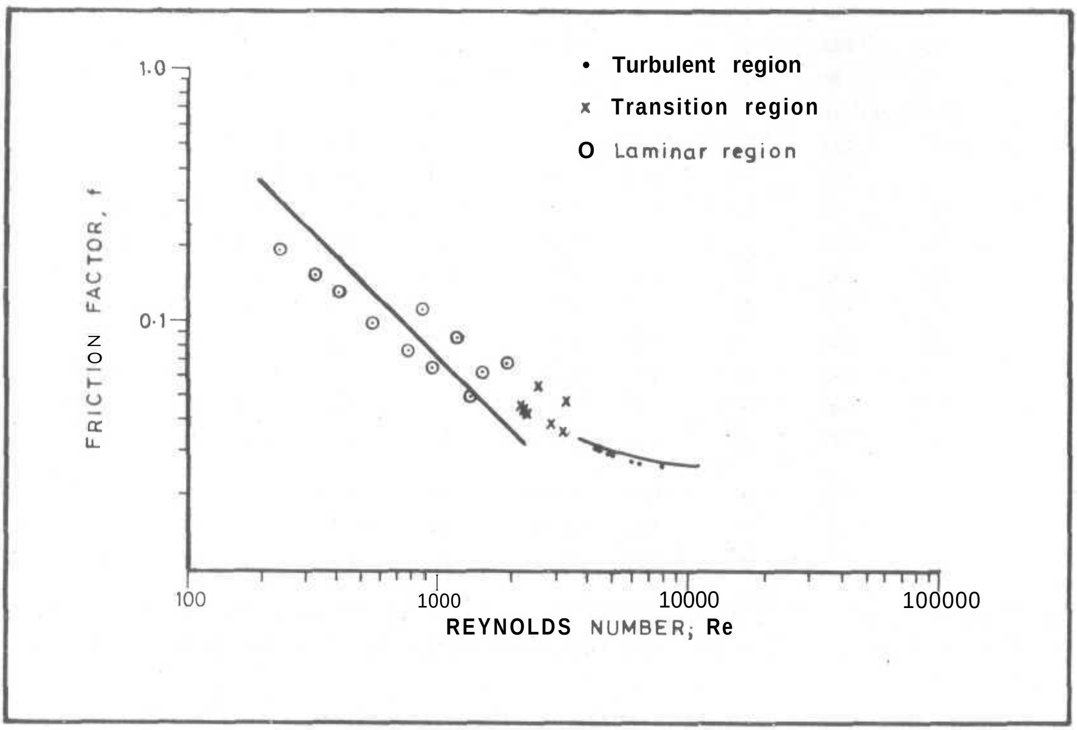

Fig.3 Reynolds number-friction factor relationship based on friction loss

Combined flow condition

$$H = 0.01402 \frac{Q^{1.23938}}{D^{3.54926}} L^{0.86030} \tag{2}$$

Turbulent flow condition

$$H = 0.00764 \frac{Q^{1.82655}}{D^{4.61537}} L^{0.77823} \tag{3}$$

Flow in transition region

$$H = 0.00817 \frac{Q^{1.56882}}{D^{3.83531}} L^{0.83541} \tag{4}$$

Laminar flow condition

$$H = 0.00796 \frac{Q^{1.23461}}{D^{3.59105}} L^{0.98712} \tag{5}$$

where

H = pressure head, which is the summation of minor loss and friction drop from the microtube, m

D = diameter of the microtube emitter, mm

Q = discharge, l/h

L = length of the microtube emitter, cm

The powers of L which should have been unity in the empirical equations for total pressure head were actually not so. This may be due to the fact that the total pressure was used in the regression analysis whereas the minor loss was done by a computer calculation using the relationship for friction drop and the minor loss function. The basic equation for friction loss has the form

$$H_f = C \frac{Q^x}{D^y} L \tag{6}$$

The minor losses include entry and exit losses, losses due to fittings and sudden contraction. The minor losses of energy have been found to vary as the square of the mean velocity of flow. Hence all the above losses can be expressed as a function of velocity head:

$$H_m = K \frac{V_2}{2g} \tag{7}$$

where

H_m = minor loss, m

K = minor loss coefficient

V = mean velocity of flow, m/s

g = acceleration due to gravity, m/s^2

The numerical solution for minor loss coefficient K was obtained by using different K values in order to make the power of 'L' unity in the estimating equation for head loss due to friction from the total discharge Q, microtube length L and diameter D.

$$H - H_m = H_f = C \frac{Q^x}{D^y} L \tag{8}$$

The minor loss equations obtained are given below:

Combined flow

$$H_m = 2.34 \frac{V^2}{2g} \tag{9}$$

Turbulent flow

$$H_m = 2.14 \frac{V^2}{2g} \tag{10}$$

Flow in transition region

$$H_m = 3.18 \frac{V^2}{2g} \tag{11}$$

Laminar flow

$$H_m = 0.84 \frac{V^2}{2g} \tag{12}$$

In this study, a K value of 0.84 was obtained for laminar flow. According to Khatri *et al.* (1979), in the laminar region the value of friction loss and total loss was same, which indicated that there was no minor loss.

When the minor loss is separated

from the total pressure head, the remaining part is the loss due to friction. The empirical equations for friction drop for microtubes were developed for different flow conditions by fitting multiple log-linear regression equations. The equations thus obtained are:

Combined flow

$$H_f = 0.00737 \frac{Q^{1.18905}}{D^{3.58352}} L \quad (13)$$

Turbulent flow

$$H_f = 0.00359 \frac{Q^{1.74866}}{D^{[illegible]}} L \quad (14)$$

Flow in transition region

$$H_f = 0.00397 \frac{Q^{1.22546}}{D^{3.58420}} L \quad (15)$$

Laminar flow

$$H_f = 0.00743 \frac{Q^{1.22546}}{D^{3.58420}} L \quad (16)$$

Two design charts were plotted to show the relationship between friction drop (expressed as per unit length) H_f/L and flow rates Q for different microtube sizes, viz, 1 mm, 2 mm and 3 mm and are presented in Fig.1 and 2. Fig.1 is plotted from equations 14, 15 and 16 for all the three flow conditions. Fig.2 is plotted from equation 13 for the combined flow condition. Since Fig.l gives design information for different flow regime, it is more accurate than Fig.2 in the microtube emitter design.

For larger pipe flow, the value of friction factor f can be determined from the Moody diagram if the numerical value of Reynolds number is known. However, for microtubes, values obtained from the Moody diagram do not hold good. An attempt was made to find out the relationship between Reynolds number Re and friction factor f in the case of microtubes.

The values of H_f were computed from equations 14, 15 and 16 for different regions. The friction factor f was calculated by using the computed values of H_f in the Darcy-Weisbach equation,

$$H_f = \frac{flv^2}{2gd} \quad (17)$$

where

H_f = head loss due to friction, m

f = friction factor

1 = length of pipe, m

v = velocity of flow, m/s

g = acceleration due to gravity, m/s^2

d = diameter of the pipe, m

By equating the different known values of H_f, the values of friction factor f were calculated for the three different regions (Table 1).

The Blasius equation and the general equation are used for calculating friction factor for larger diameter pipe in turbulent and laminar region respectively. The equations for friction factor f of microtube emitters for turbulent and laminar flow were determined by computer analyses. Similar to Blasius equation, an equation was developed for turbulent flow. The Blasius equation for turbulent flow is

$$f = \frac{0.316}{Re^{0.25}} \quad (18)$$

where

f = friction factor

Re = Reynolds number

The equation developed in the present study is

$$f = \frac{0.248}{Re^{0.25}} \quad (19)$$

The general equation for laminar flow is

$$f = \frac{64}{Re} \quad (20)$$

The equation developed for laminar region is

$$f = \frac{67.2}{Re} \quad (21)$$

In the transition region, generally no relationship exists between friction factor f

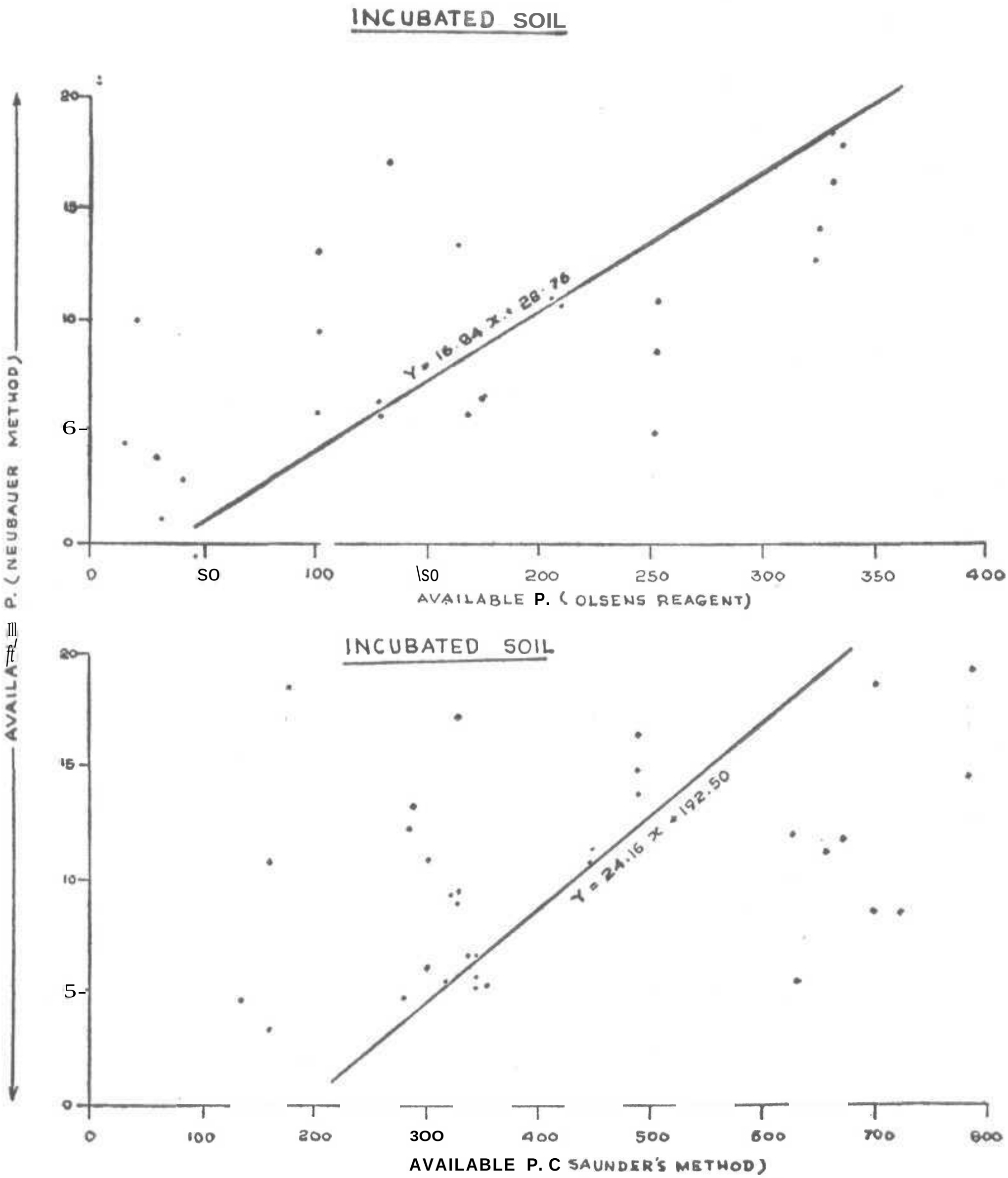

Fig. 1. Correlation between available P as determined by the Neubauer's method and P extracted by Olsen's and Saunder's methods.