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A SIMPLE MODEL FOR DESIGNING MICROIRRIGATION LATERAL WITH THE MICROTUBE AS AN EMISSION POINT

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ABSTRACT

Studies were conducted to evaluate the friction factor in polyethylene pipes applying Darcy-Weisbach equation. Results of the investigation have been used to apply modeling techniques to form a simple model for designing single microirrigation lateral with the microtube as an emission device that was simulated the uniformity coefficient of water application. The experimental investigation showed that the average friction factor, relative roughness and absolute roughness values were found 0.039081, 0.0063 and 0.084 mm respectively for polyethylene pipe size 13.35 mm I. D., the average friction factor, relative roughness and absolute roughness values were found 0.039074, 0.0073 and 0.118 mm for polyethylene pipe size 16.15 mm I. D. and the average friction factor, relative roughness and absolute roughness values were found 0.037328, 0.005 and 0.09 mm for polyethylene pipe size 18.2 mm I. D. A computer model was applied for designing single microirrigation lateral with the microtube as an emission device using the experimental data that was simulated the uniformity coefficient of water application.

INTRODUCTION

Microirrigation lateral deliver irrigation water to the plant-root zone through emitters in microirrigation system. The flow condition in the microirrigation lateral can be considered to be steady and spatially varied with emitter outflows. Among the various microirrigation systems, microtube system is to be more economical. The hydraulic characteristic of microtube system differs from other systems owing to its diameter and length. For a given tube length and diameter, the discharge rate is a function of the pressure head.

Microtube system has many problems that affect system uniformity where microtube emitters are used in microirrigation system. The major factors caused low uniformity coefficient including, friction drop along the microirrigation lateral and designed microtube emitters characteristics.

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Ideally, the application of throughout a microirrigation system should be absolutely uniform: this would require that each microtube emitter have the same rate of discharge even through pressure losses are unavoidable.

The first objective of this paper is to calculate the friction factor and absolute roughness in polyethylene pipes. The second objective is to apply modeling techniques to form a simple model for designing single microirrigation lateral with the microtube as an emission device using the experimental data that was simulated the uniformity coefficient of water application.

REVIEW OF LITERATURE

von Bernuth and Wilson (1989) studied three small diameter plastic pipe sections to determine the friction factor *f* by using Blasius equation and Colebrook-White (C-W) equation (1). The results indicate that the Blasius equation is a very accurate predictor of the friction factor when Reynolds numbers are less than 100000.

$$\frac{1}{\sqrt{f}} = -0.86 \ln\left[\frac{\varepsilon}{3.76D} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right] \tag{1}$$

where; f = friction factor; ε = Pipe roughness (mm); D = Pipe diameter (mm) and Re = Reynolds number.

They added that the Colebrook-White equation is valid for Re less than 4000 and ε /D ranging between 10^{-6} and 10^{-2}.

Swamee and Jain (1976) developed the Colebrook-White equation, equation (1), to determine friction factor as the following:

$$f = 1.325\left[\ln\left(\frac{\varepsilon}{3.7D} + \frac{5.74}{\mathrm{Re}^{0.9}}\right)\right]^{-2} \tag{2}$$

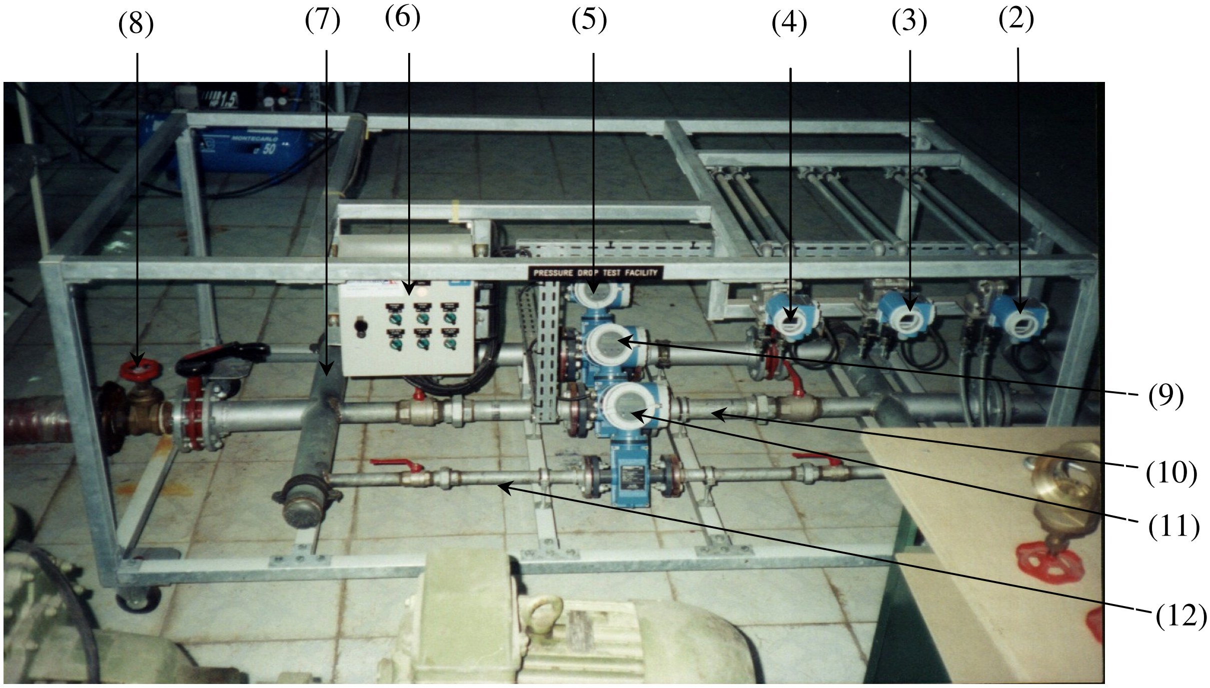
They added that this equation is valid for Re ranging between 5000 and 10^8 and ε /D ranging between 10^{-6} and 10^{-2}.

Swamee (1993) reached to determine the friction factor in the laminar, the transition and the turbulent flow conditions for Re ranging between 1 and 10^8.

$$f = \left\{\left(\frac{64}{\mathrm{Re}}\right)^{8} + 9.5\left[\ln\left(\frac{\varepsilon}{3.7D} + \frac{5.74}{\mathrm{Re}^{0.9}}\right) - \left(\frac{2500}{\mathrm{Re}}\right)^{6}\right]^{-16}\right\}^{0.125} \tag{3}$$

MATERIALS AND METHODS

The first objective of the laboratory experiment was to evaluate friction factor in polyethylene pipes by using pressure drop test facilities apparatus as shown in figure (1). The experimental investigation was carried out in Hydraulic National



(1) Pressure transducer (0-0.5 bar)
(2) Pressure transducer (0-2.0 bar)
(3) Pressure transducer (0-5.0 bar)
(4) Line 1.0"
(5) Electromagnetic flow meter (0-100 m^3/h)
(6) Control panel
(7) Submain line 2.5"
(8) Valve water inlet 2.5"
(9) Electromagnetic flow meter (0-50 m^3/h)
(10) Line 0.75"
(11) Electromagnetic flow meter (0-5 m^3/h)
(12) Line 0.5"

Fig. (1): Pressure drop test facilities.

Lab of Agricultural Engineering Research Institute (AEnRI), Dokki, Giza. The experiments were conducted at 23 °C water temperature. Low-density polyethylene pipes 40 m long, with inside diameters of 13.35, 16.15 and 18.2 mm were used in the experiments. These sizes represent the practical sizes used in microirrigation systems. The volume of water flowed from each pipe was measured for ten minutes to calculate the flow rate. The pressure drop of each pipe was measured at twelve values of flow rate.

The second objective of the present research was to design simple model consisting of single lateral in microirrigation system with the microtube as an emission device is shown in fig. (2), where q = is the discharge of the microtube (L/h); p = is the pressure at inlet of the microtube emitter (bar); d = is the inside diameter of microtube emitter (mm); l = is the length of the microtube (m); Q = is the flow rate of the lateral (L/h); S = is the space between microtubes and L = is the length of the lateral (m).

This simple model for designing single microirrigation lateral was used for predicting the uniformity coefficient of water application for microirrigation system using the microtube as an emission device. In order to simplify the model, some assumptions are made:

1. Internal diameter of lateral is 13.35, 16.15 and 18.2 mm.
2. Internal diameter of microtube is 3.15 and 4.3 mm.
3. Length of microtube is 0.25, 0.5 and 1.0 m.
4. Material of lateral and microtube is polyethylene.
5. Discharge of microtube was calculated using the empirical equation obtained (4) by Hanafy et al. (2005).

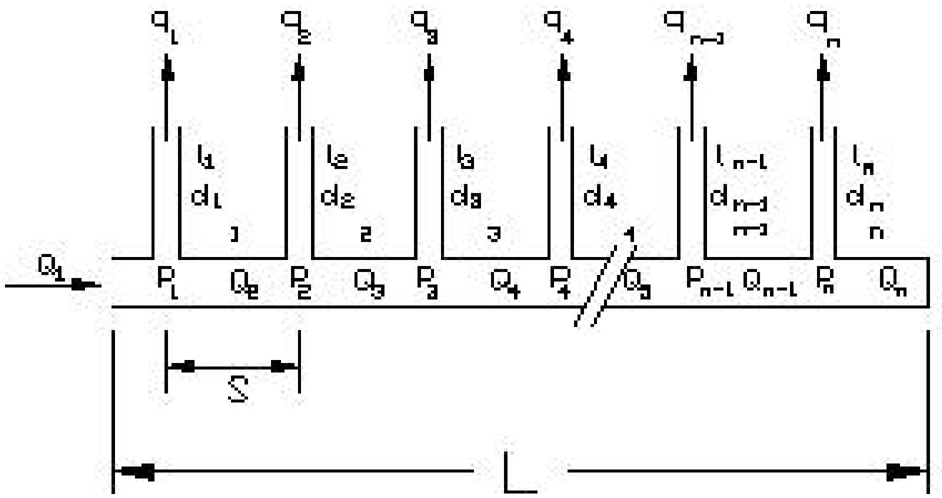


Fig. (2): Simple model consisting of single lateral in microirrigation system.

1. **Numerical solution**

A computer program was designed by using a version 6 of Visual Basic program for:

1. Choose a series of values for the inside lateral diameter (D), the lateral length (*L*), the inlet pressure head of lateral (*p*), the inside microtube diameter (*d*), the number of microtube (*N*) and microtube length (*l*).
2. Predict the microtube discharge using the empirical equation, which obtained (4) by Hanafy et al. (2005).
3. Calculate a space between microtubes on lateral line.
4. Determine the flow rate along the lateral line.
5. Evaluate the Reynolds number along the lateral line.
6. Estimate the friction factor along the lateral line.
7. Calculate the pressure head along lateral line.
8. If the number of microtube (*N*) is not equal at microtube (*i*). In this case, the microtube (i) equal microtube (*i-1*), then repeat the calculation of microtube discharge from step 2.
9. If the number of microtube (*N*) is equal at microtube (*i*), then determine the average microtube discharge.

10. Evaluate the uniformity coefficient of water application.

2. Hydraulic analysis

2.1 **Determination of the microtube discharge**

The discharge rate form microtube emitter was calculated by applying the Hanafy et al. (2005) as shown in fig. (3):

$$q = kp^{a} d^{b} l^{c} (d / D)^{e} \qquad (4)$$

in which q = the discharge of the microtube (L/h); p = the pressure at entrance of microtube (bar); d = the inside diameter of microtube (mm); l = the length of microtube emitter (m); D = the inside diameter of lateral (mm); and k, a, b, c, e = 2.8, 0.62, 2.54, -0.26 and -0.5 respectively.

2.2 **Estimation of the space between microtube**

Obtain a space between microtubes is presented in fig. (3), and determined by:

$$S_{(i)} = L_{(i)} / (N - 1) \qquad (5)$$

2.3 **Calculation of the flow rate along lateral line**

To estimate flow rate along lateral line, the next equation was used as shown in fig. (3):

$$Q_{L(i)} = Q_{L(i+1)} + q_{(i)} \qquad (6)$$

2.4 **Determination of the Reynolds number along lateral line**

The Reynolds number along lateral line was determined from the next equation as shown in fig. (3):

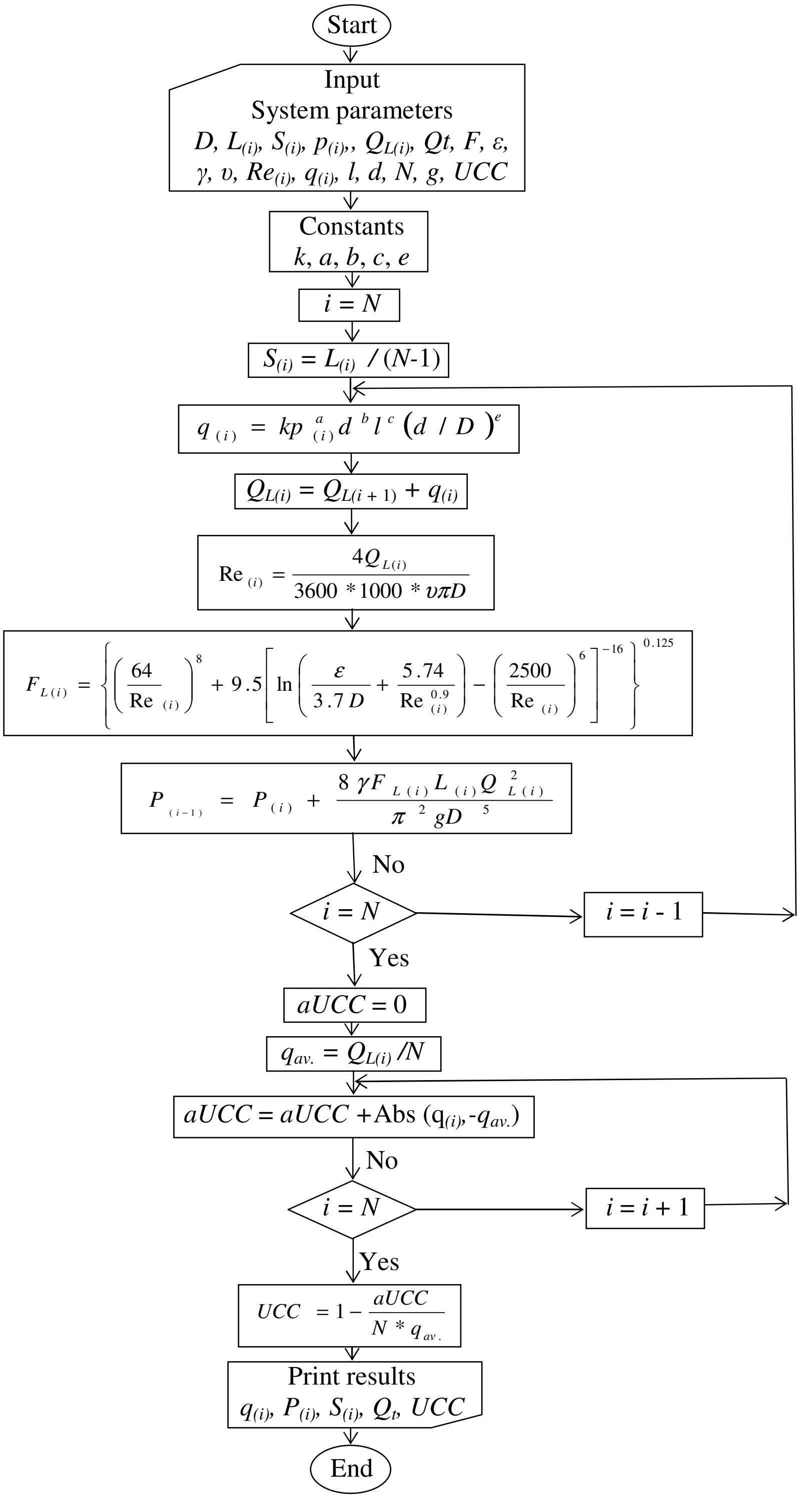


Fig. (3): Flowchart of computer program for designing single microirrigation lateral.

$$Re_{(i)} = \frac{4Q}{3600 * 1000\ \upsilon \pi D} \qquad (7)$$

where; Re = Reynolds number; k = constant equal to 3600 for the metric system and υ = kinematic viscosity of water at 23 ºC (0.941 $*10^{-6}$ m^2/s).

2.5 **Estimation of the friction factor along lateral line**

The friction factor along lateral line was calculated by applying the Swamee (1993) equation (3) as shown in fig. (3).

2.6 **Calculation of the pressure head along lateral line**

By using the Darcy-Weisbach equation we can calculate the pressure head along lateral line as shown in fig. (3):

$$P_{(i-1)} = P_{(i)} + \frac{8 \gamma F_{L(i)} L_{(i)} Q^2_{L(i)}}{\pi^2 g D^5} \qquad (8)$$

where; $P_{(i)}$ = the pressure head along lateral line (N/m^2); γ = the specific weight (N/m^3); $F_{L(i)}$ = the friction factor; $L_{(i)}$ = the length of pipe (m); $Q_{L(i)}$ = the flow rate along lateral line (L/h); D = the inside lateral diameter (mm) and g = the gravitational acceleration, m/s^2.

2.7 **Evaluation of the Christiansen's uniformity coefficient**

Christiansen's uniformity coefficient is used here to express uniformity of water application (Keller and Karmelli, 1975):

$$UCC = 1 - \frac{1}{Nq_{avg}} \sum_{i=1}^{N} \left| q_i - q_{avg} \right| \qquad (9)$$

where; UCC = Christiansen's uniformity coefficient; N = the number of emitters; q_{avg} = the average emitter discharge (L/h) and q_i = the discharge of emitter (L/h).

RESULTS AND DISCUSSION

The experimental data showed that the Reynolds number was found to increase from 6376.8 to 16779.6 for the microirrigation lateral size of 13.35 mm I. D. as shown in fig. (4), the Reynolds number was found to increase from 8971.6 to 21613.3 for the microirrigation lateral size of 16.15 mm I. D as shown in fig. (5) and the Reynolds number was found to increase from 11327.2 to 26947.8 for the microirrigation lateral size of 18.2 mm I. D. as shown in fig. (6) The total range of Reynolds number was found to be on the side of the turbulent range.

The average friction factor, relative roughness and absolute roughness values were found 0.039081, 0.0063 and 0.084 mm respectively for polyethylene pipe size 13.35 mm I. D. The average friction factor, relative roughness and absolute roughness values were found 0.039074, 0.0073 and 0.118 mm for polyethylene pipe size 16.15 mm I. D. The average friction factor, relative roughness and absolute roughness values were found 0.037328, 0.005 and 0.09 mm for polyethylene pipe size 18.2 mm I. D.

The measured pressure drop was found to increase gradually from 131 to 725 mbar for the microirrigation lateral size of 13.35 mm I. D. as shown in fig. (7). The measured pressure drop was found to increase gradually from 145 to 688.5 mbar for the microirrigation lateral size of 16.15 mm I. D. as shown in fig. (8). The measured pressure drop was found to increase gradually from 151 to 738 mbar for the microirrigation lateral size of 18.2 mm I. D. as shown in fig. (9). The results in the figures (7) through (9) indicate that the effect of lateral diameter on measured and calculated pressure drop is highest for small lateral diameter 13.35 mm I. D. and that with increasing of lateral diameter the measured and calculated pressure drop will decrease.

A computer model for designing single microirrigation lateral with the microtube as an emission device was constructed to determine the microtube discharge and operating pressure at inlet of the microtube; to calculate the total flow rate along lateral line; to estimate the Reynolds number along lateral line; to predict the friction factor along lateral line; to calculate the head loss along lateral line and to evaluate the Christiansen’s uniformity coefficient.

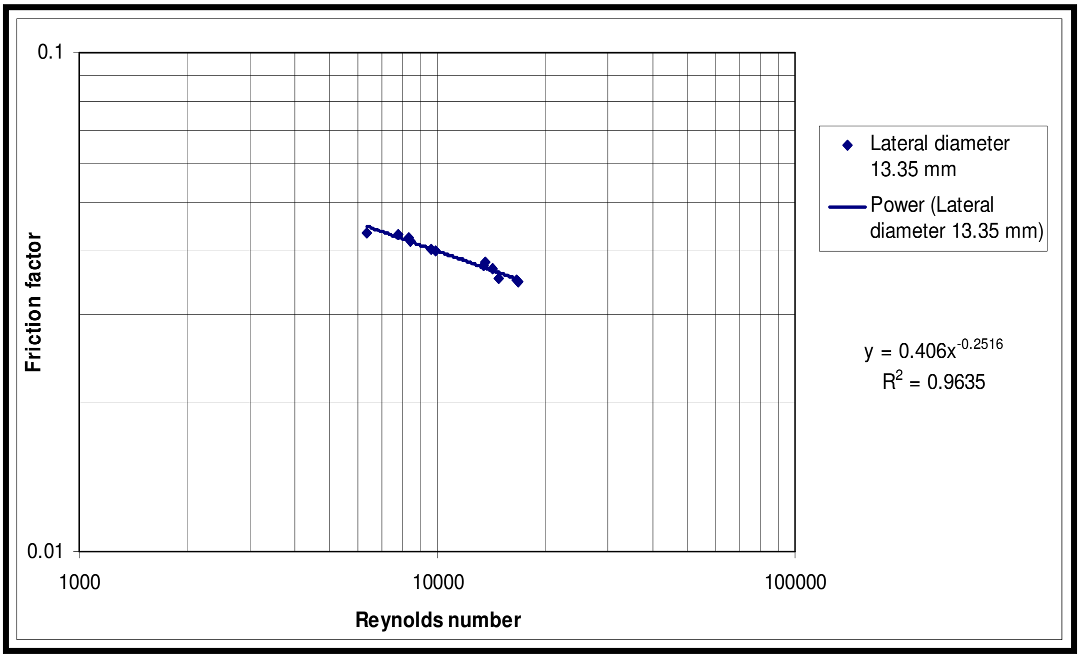


Fig. (4): Relationship between Reynolds number and friction factor for 13.35 mm polyethylene pipe.

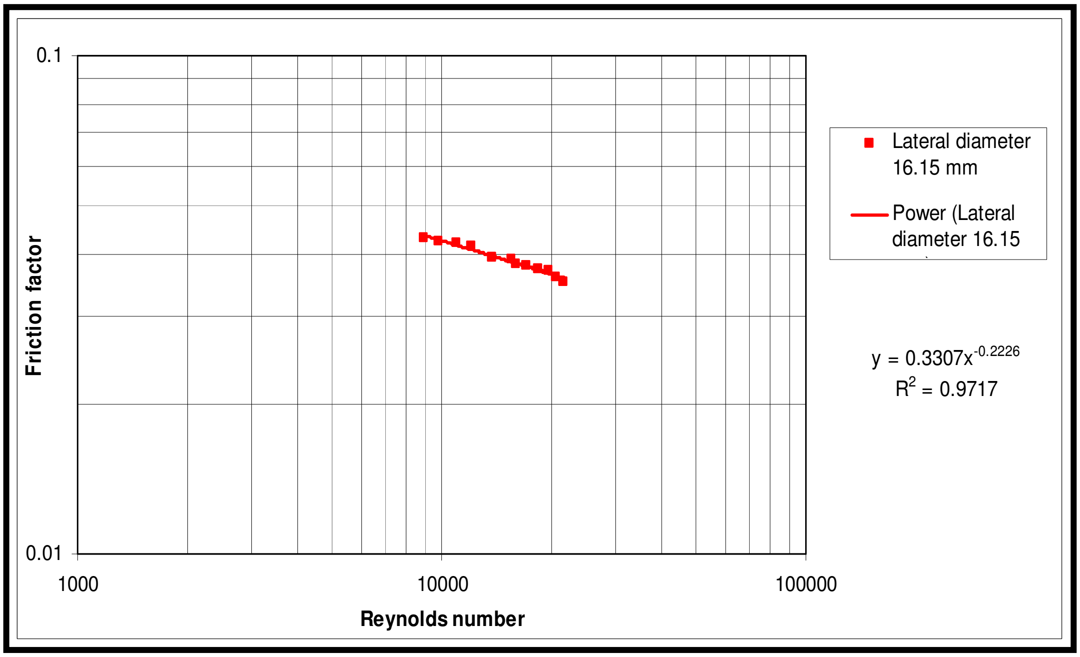


Fig. (5): Relationship between Reynolds number and friction factor for 16.15 mm polyethylene pipe.

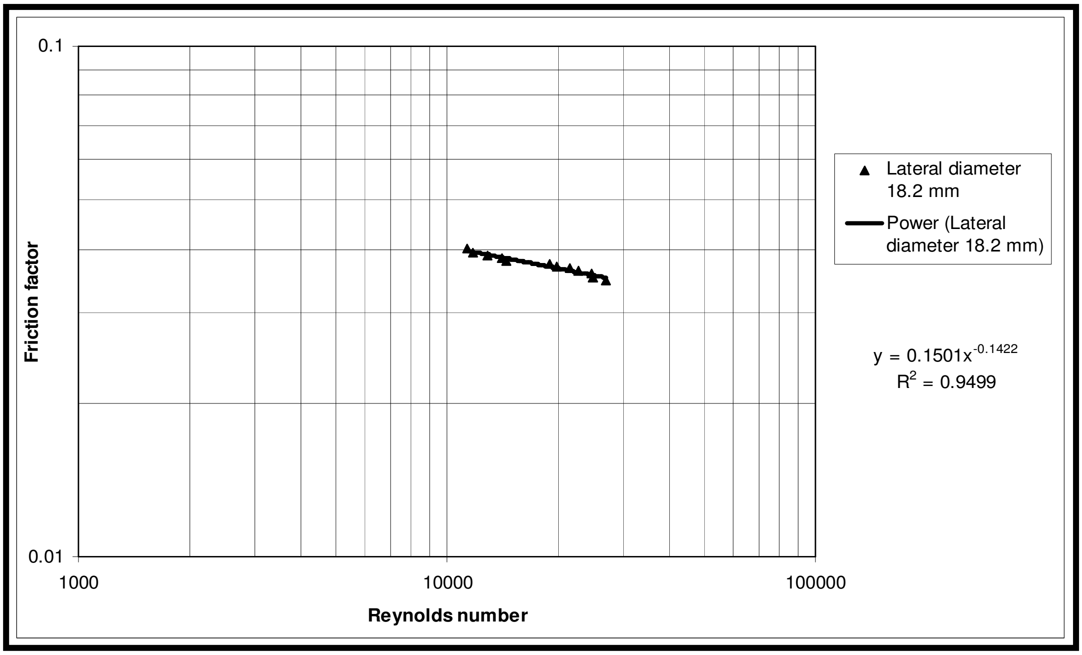


Fig. (6): Relationship between Reynolds number and friction factor for 18.2 mm polyethylene pipe

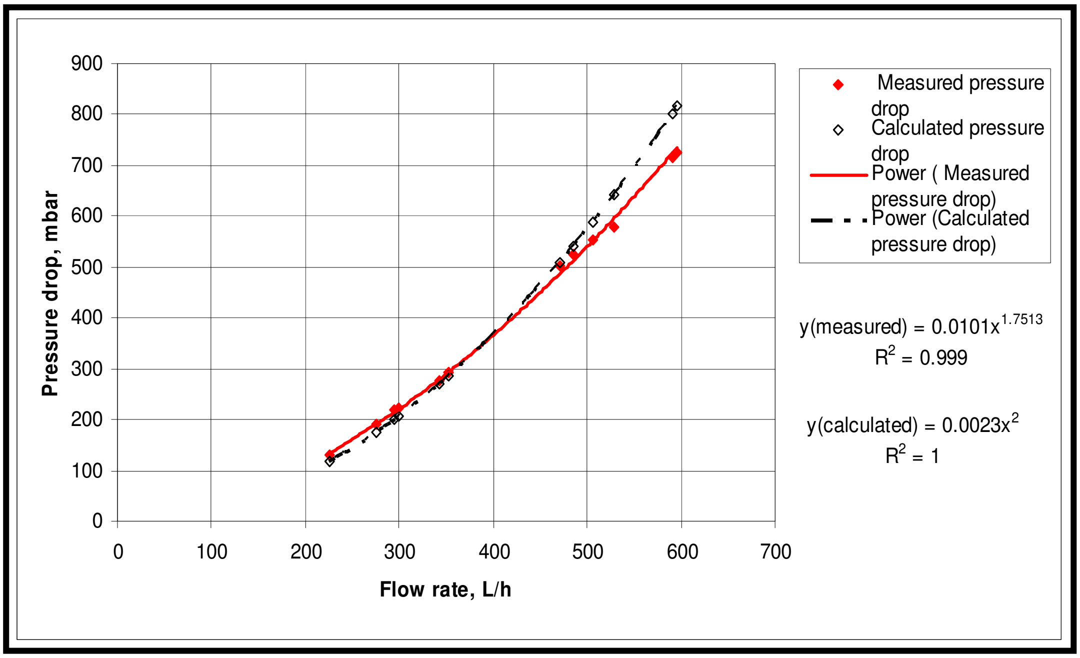


Fig. (7): Comparison between measured and calculated pressure drop for 13.35 mm polyethylene pipe.

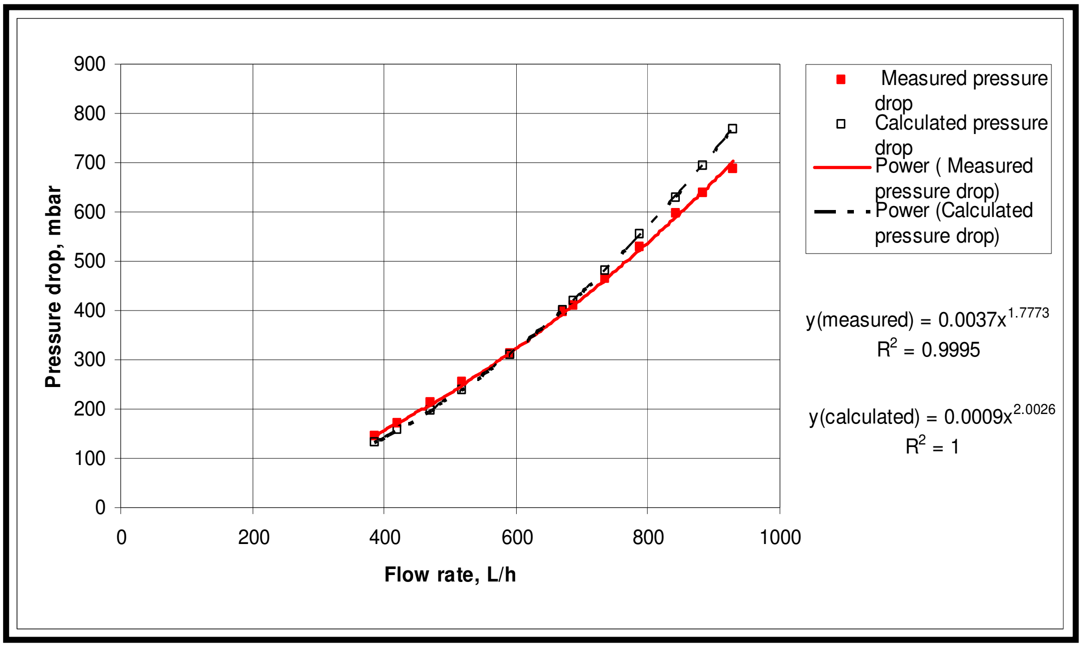


Fig. (8): Comparison between measured and calculated pressure drop for 16.15 mm polyethylene pipe.

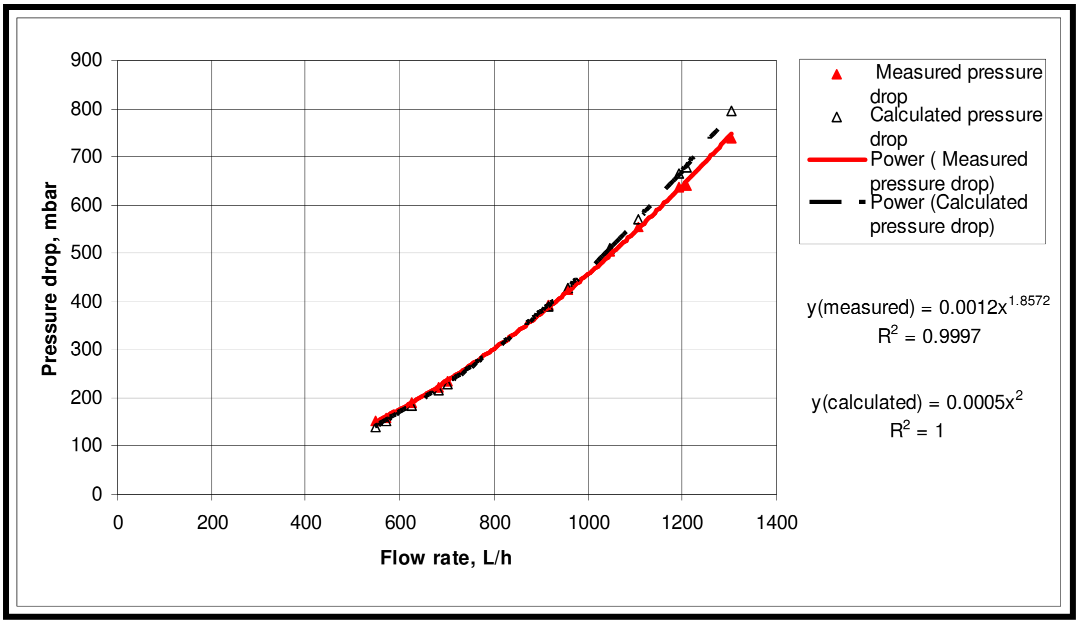


Fig. (9): Comparison between measured and calculated pressure drop for 18.2 mm polyethylene pipe.

CONCLUSION

The laboratory experiments indicated that the average friction factor, relative roughness and absolute roughness were found 0.039081, 0.0063 and 0.084 mm respectively for polyethylene pipe size 13.35 mm I. D. The average friction factor, relative roughness and absolute roughness values were found 0.039074, 0.0073 and 0.118 mm for polyethylene pipe size 16.15 mm I. D. The average friction factor, relative roughness and absolute roughness values were found 0.037328, 0.005 and 0.09 mm for polyethylene pipe size 18.2 mm I. D. The lateral diameter effect on measured and calculated pressure drop is highest for small lateral diameter 13.35 mm I. D. and that with increasing of lateral diameter the measured and calculated pressure drop will decrease.

A computer model is applied for designing single microirrigation lateral with the microtube as an emission device using the experimental data that was simulated the uniformity coefficient of water application.

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الملخص العربي

برنامج حاسب آلي لتصميم خط فرعى في نظام الرى الدقيق باستخدام الأنبوب الدقيق كنقطة بث

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يعتبر نظام الري الدقيق أحد التقنيات الحديثة لإمداد المياه إلى الحقل. الأنابيب الدقيقة نموذج مبسط من المنقطات تتميز بأنها سهلة التركيب ومنخفضة التكاليف مقارنة ببقية الأنواع الأخرى من المنقطات. يتم اختيار أطوال قصيرة وأقطار صغيرة من الأنابيب الدقيقة للحصول علي معدلات تصرف مختلفة، لذلك فهي تستخدم كمنقطات.

ونظراً لانخفاض انتظامية التوزيع المائي من الأنابيب الدقيقة عند استخدامها فى شبكة الرى الدقيق ، فإن ذلك يتطلب تنظيم تغيرات الضغط المختلفة أو أطوال الأنابيب الدقيقة على امتداد شبكة الرى. ولكي يمكن الحصول علي معامل عالي لانتظام توزيع المياه من الأنابيب الدقيقة فإن ذلك يتطلب دراسة هيدروليكا الأنابيب الدقيقة.

ولذلك صمم برنامج حاسب آلي وذلك باستخدام نتائج التجارب العملية للأغراض التالية: (١) حساب كمية التصرف الخارجة من الأنبوب الدقيق ؛ (٢) حساب معامل الاحتكاك ورقم رينولد للخطوط الفرعية المصنعة من مادة البولي ايثليين؛ (٣) التنبؤ بمعامل انتظام توزيع المياه للأنابيب الدقيقة.

<u>ومن هنا كان الهدف من الدراسة هو:</u>

(١) حساب معامل الاحتكاك والخشونة النسبية للخطوط الفرعية المصنعة من مادة البولي ايثليين.
(٢) إنشاء برنامج باستخدام الحاسب الآلي لخط فرعى مفرد مصنع من مادة البولي ايثليين حيث وضعت عليه الأنابيب الدقيقة تعمل كمنقطات.

أجريت التجربة العملية باستخدام ثلاثة أقطار داخلية من الخطوط الفرعية المصنعة من مادة البولي ايثليين (١٣,٣٥، ١٦,١٥، ١٨,٢ مم) طول كل قطر ٤٠ متر عند درجة حرارة ٢٣ °م، واختبر كل قطر عند أثنى عشر فروق ضغوط مختلفة. أوضحت النتائج أن متوسط معامل الاحتكاك والخشونة النسبية والخشونة المطلقة لخط فرعى مصنع من مادة البولي ايثليين ذات قطر داخلي ١٣,٣٥ مم هي على الترتيب ٠,٠٣٩٠٨١، ٠,٠٠٦٣، ٠,٠٨٤ مم. كذلك متوسط معامل الاحتكاك والخشونة النسبية والخشونة المطلقة لخط فرعى ذات قطر داخلي ١٦,١٥ مم هي على الترتيب ٠,٠٣٩٠٧٤، ٠,٠٠٧٣، ٠,١١٨ مم. وأيضاً وجد أن متوسط معامل الاحتكاك والخشونة النسبية والخشونة المطلقة لخط فرعى ذات قطر داخلي ١٨,٢ مم هي على الترتيب ٠,٠٣٧٣٢٨، ٠,٠٠٥، ٠,٠٩ مم.

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