COMPARATIVE ANALYSIS OF TEST RESULTS OF DRIP LATERALS WITH CIRCULAR AND ELLIPTIC CROSS SECTION

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Abstract: Lately, the drip irrigation systems find more and more application, which led to the production of a new type of drip laterals – with flat to elliptic cross section and comparatively small thickness of the wall – from 0.2 to 0.9 mm, compared to the conventional ones with circular cross section and wall thickness over 1 mm. The main advantage of the first type is that they are comparatively cheap and are offered in the form of small rolls, the length of the hose being from 500 to 3500 m which makes their transportation to warehouses, assembly and disassembly very convenient. With the smaller thickness of the walls, the laterals have almost clenched form and are intended to be used for one irrigation season, while those with higher thickness, with elliptic form, may be used for several seasons. The inside welded emitters are flat and have a very small water-stopping head area compared to the annular water-stopping cross section of the cylindrical drippers in the conventional circular type of laterals. This is connected with the smaller head losses in the movement of water in them, which is an important advantage. The paper presents and analyses the results of the hydraulic test of the two types of drip hoses – with circular and elliptic cross section, in order to find the head losses for different lengths - 40, 60 and 80 m and heads in the beginning of 6, 8, 10, 12, 14 and 16 m, as well as the coefficients of uniformity for both types. The following hoses of both types were tested: JUNIOR, with circular cross section and internal diameter of 13.8 mm, nominal diameter 16 mm, thickness of wall 1.1mm, cylindrical type of drippers with a flow rate of 2.1 l/h and interval between nozzles 0.30 m (Irritec, Italy); DP Line (D5), with elliptic cross section, with the same sizes and intervals but with a wall thickness 0.6 mm and flat type of drippers (Irritec, Italy). The results indicate that irrespectively of the elliptic form of the cross section which is with a very small hydraulic radius, the head losses are almost equal to those with the circular cross section with cylindrical drippers, which is due to the minor head losses because of the flat nozzles in them. The values of the absolute coefficient of uniformity and the calculated one according to the method of Christiansen for all options are presented. The test is performed for zero slope, while modelling is performed for slopes 1% and 2%. The analysis of the data indicates that for zero slope of the terrain the increase of head leads to increase of the coefficients of uniformity for the three tested lengths of laterals; for 1% are observed very small tendencies for reduction of those coefficients, while for 2% the coefficients have higher values compared to the other slopes, again with slightly expressed tendency for change. The higher values in the 2% slope are due to the additional head caused by the geodetic level difference of the terrain.
Keywords: drippers (emitters), head losses along drip laterals, minor head losses, coefficients of uniformity

1. INTRODUCTION

Lately, a number of companies manufacturing drip irrigation systems offer drip laterals with two forms of cross section in non-operational (transportation) state – circular, with big wall thickness, and elliptic (clenched) form with smaller wall thickness and nominal diameters of polyethylene, low-density pipes – 16 and 20 mm.
In the circular type, usually the wall thickness is higher than 1.1 mm, and the laterals are delivered in rolls of comparatively large-dimension volume and diameter 1-1.5 m. What is specific for these drip laterals is that due to their strength parameters they are intended for a long-lasting use, over 10 years, mainly for stationary application, i.e. without assembly and disassembly each year. The length of the pipe in a roll is usually 100-400m.
In the elliptic form of the laterals the wall thickness is comparatively small – from 0.2 to 0.9 mm, the smaller thicknesses being used for one season (the so called "ephemeras"). Because of their small dimensions they are delivered by the manufacturer packed in rolls, 500-3500 m length of pipe, at low cost, which is a great advantage during the installation. As a whole, the life time of these hoses is much smaller compared to the first type, and in most cases they are intended for seasonal (non-stationary) operation. From hydraulic point of view, it should be noted that with their putting into operation, the cross section is altered from highly extended elliptic (clenched) form to a nearly circular form with the higher heads which is connected with the alteration of their hydraulic characteristics, and respectively, alteration of their conductivity at certain head. With their clenched form, the

hydraulic radius is very small – approx. 0.2 with internal diameter 13.8 mm and rate of opening in the middle 1 mm. With the increase of the operating head the ellipse is opening and this radius is gradually increasing reaching in the best case values near to the value of the radius in a circular cross section - 3.45 (equal to 1/4 of the pipe diameter). Having in mind the physical essence of the hydraulic radius, the comparison of these values indicates that the radius in case of a fully open form of the elliptic cross section is about 17 times bigger than the one in the clenched form, and it is following from this that the open cross section at certain operating head has a bigger conductivity, and the hydraulic losses from friction in the water running in these drip laterals are considerably smaller.

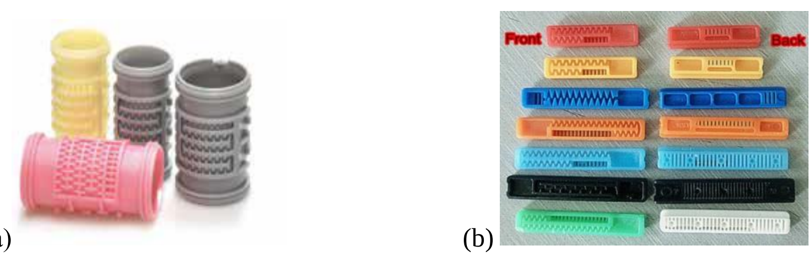
2. CHARACTERISTICS OF THE INSIDE WELDED EMITTERS

2.1. In laterals with circular cross section

In these laterals, the inside welded emitters has a cylindrical form (Fig. 1a) with a labyrinth type canal, with a flow rate of 2 to 7 l/h, and the comparatively large operating area on which the canal is located allows this canal to have considerably larger cross section, which prevents it from clogging. There are also less requirements for treatment of the irrigation water, and less energy consumption by these emitters at certain value of the flow rate of dripping. But, at the same time, it should be noted that the so arranged annular water-stopping cross section of those nozzles along the whole internal contour of the hoses is a precondition for creation of higher minor head losses during the run of water in them, due to the comparatively large water-stopping annular area.

2.2. In laterals with elliptic cross section

In these laterals, the inside welded emitters are of the flat type (Fig. 1b), with rectangular form. The operational flow rate is comparatively small and varies usually from 0.8 to 4 l/h, while the canal is also of labyrinth type but with considerably smaller cross section due to the smaller operating area on the surface of the nozzles, and in spite of this all nozzles operate in the quadratic part of the water movement (the exponent in the equation of the key curve x = 0.5). In this case, there are higher requirements to the treatment of the irrigation water and its qualities. But in contrast to the cylindrical drippers, here the cross water-stopping section of the nozzles along the internal contour of the hoses is part of an arc featuring a small area of stopping of the water stream which is a precondition for realization of minor head losses in the irrigation laterals. This is an essential advantage, but in both cases this can be proved through the conduction of experimental hydraulic tests.



(a) (b)

Fig. 1. Drippers Type – (a) - cylindrical; (b) - flat [6]

3. SCHEME OF THE TEST SETUP

In order to conduct the hydraulic investigations on both types of drip laterals, a test setup was created (Fig. 2) in the laboratory. It allowed the maintenance of a steady lower water level to the pump (10) through the compensating reservoir (8), and from there, maintenance of a steady operating head of the pump during the test [5]. The tested laterals (3) were fixed horizontally, hanged over vertical steel rods (2) on concrete cubes (1). Due to the comparatively small operating flow rates, for providing the normal operation of the pump a by-pass connection (7) was realized to the compensating reservoir. The water supply was realized from the water mains and a screen filter (6) was installed at the beginning of the laterals.

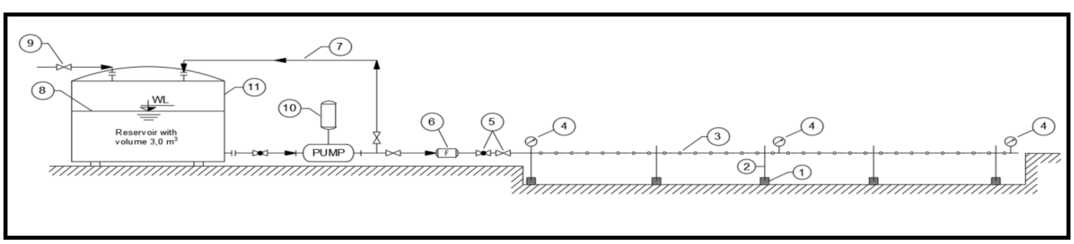


Fig. 2. Experimental setup for testing the laterals for drip irrigation

1 – concrete cube; 2 – steel rods; 3 – lateral on steel wire; 4 – pressure gauge; 5 – valves for regulation of inlet pressure; 6 – screen filters; 7 – by-pass between pump and reservoir; 8 – water level in reservoir; 9 – water supply; 10 – pump; 11 – reservoir with volume 3,0 m^3.

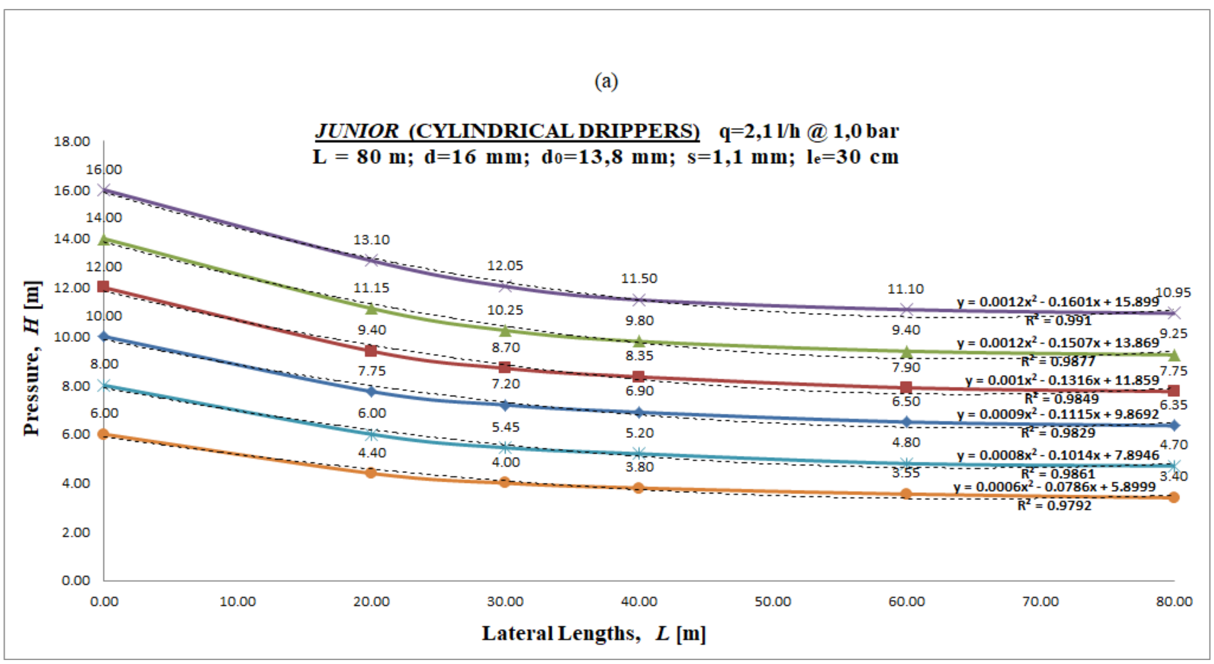
4. METHODS OF INVESTIGATION

In order to perform the comparative analysis of the test results, drip laterals of both types were chosen – with equal internal diameter and nominal outer diameter, equal flow rate of the drippers and equal intervals between nozzles manufactured at one and the same production line. These are the laterals:

- ***JUNIOR***, with circular cross section, with internal diameter d_0 = 13.8 mm, nominal diameter d = 16 mm, wall thickness s = 1.1 mm, flow rate q_k = 2.1 l/h and interval between nozzles 0.30 m. Flow rate-pressure equation $q = 0.66*H^{0.5}$ - (Irritec, Italy);
- ***DP Line (D5)***, with elliptic cross section, internal diameter d_0 = 13.8 mm, nominal diameter d = 16 mm, wall thickness s = 0.6 mm, flat type drippers with a flow rate q_k = 2.1 l/h and spacing between nozzles 0.30 m. Flow rate-pressure equation $q = 0.69*H^{0.48}$ - (Irritec, Italy).

In order to follow the variation of the head line along the length of the laterals, and at the same time taking into consideration the hydraulic losses, the head measurement was performed through intervals of 20 m. Taking into account the possible scope of operation in practice, the following values of the inlet pressure were selected: 6, 8 10, 12, 14 and 16 m, and length of laterals – 40, 60 and 80 m.

Since the specific measurement of the flow rates of the drippers at all detailed points along the length of the laterals (20 pcs, according to [8]) is connected on one hand with certain failures during the measurement, and on the other hand the influence of the coefficient of technological variation Cv could cause additional failures and this could affect the authenticity of the final results obtained, then, knowing the elevations from the measurement of the head line (through intervals of 20 m) the equations of these curves were obtained (Fig. 3) where from through the flow rate-pressure relationship of the drippers, the values of the flow rates at the detailed points were obtained. On the basis of the so obtained flow rate values were determined the absolute coefficient of uniformity U_C^{ABS} and the coefficient of uniformity determined according to the formula of Christiansen U_C^{CHR}, given in Table 1. In order to expand the scope of investigation, then, from the so obtained results for a horizontal terrain, S = 0, through simulation were obtained also the coefficients of uniformity for terrain slopes S = 1% and S = 2 %.



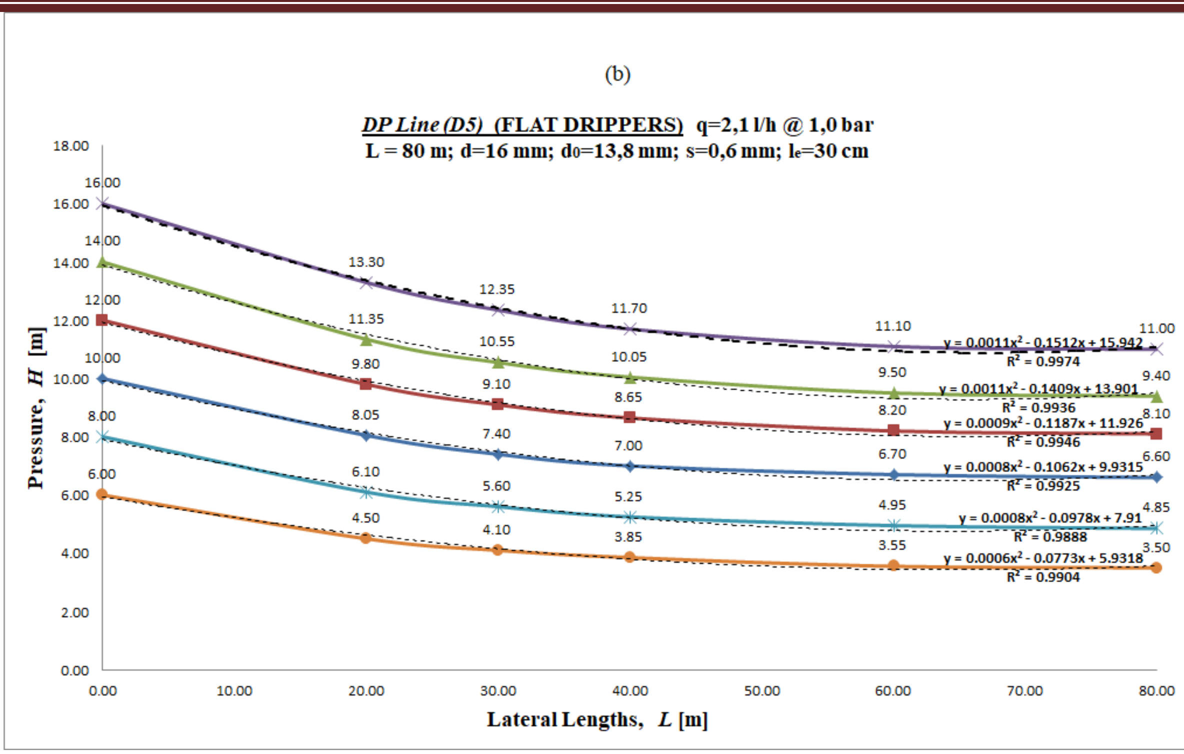


Fig. 3. Results of hydraulic tests for pressure distribution along the lateral length with 16 mm nominal diameter for drip irrigation with cylindrical (a) and flat (b) drippers at 30 cm spacing

Table 1. Uniformity coefficient in percent according to Christiansen $\left(U_C^{CHR}\right)$ and in absolute value $\left(U_C^{ABS}\right)$ at different slopes and lengths of lateral with circular and elliptic cross-section.

Inlet Pressure H_{in}, m	Slope																		Cross section type
	$S = 0$						$S = 1.0$ %						$S = 2.0$ %						
	Lateral lengths																		
	40 m		60 m		80 m		40 m		60 m		80 m		40 m		60 m		80 m		
	U_c^{ABS}	U_c^{CHR}	U_c^{ABS}	U_c^{CHR}	U_c^{ABS}	U_c^{CHR}	U_c^{ABS}	U_c^{CHR}	U_c^{ABS}	U_c^{CHR}	U_c^{ABS}	U_c^{CHR}	U_c^{ABS}	U_c^{CHR}	U_c^{ABS}	U_c^{CHR}	U_c^{ABS}	U_c^{CHR}	
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	
6	95.83	98.84	89.57	96.97	75.09	91.75	98.30	99.59	93.55	98.42	81.72	94.65	97.11	99.24	95.89	98.89	87.04	96.69	C
	94.30	98.40	86.79	96.12	77.01	92.54	96.80	99.24	90.73	97.65	83.21	95.21	97.54	99.41	93.88	98.41	88.18	96.99	E
8	96.10	98.91	88.70	96.68	77.01	92.58	98.03	99.54	91.86	97.85	81.82	94.69	98.08	99.56	94.46	98.66	85.90	96.34	C
	95.00	98.59	89.89	97.09	79.63	93.66	97.05	99.25	92.82	98.17	84.01	95.54	98.54	99.59	95.19	98.80	87.71	96.87	E
10	96.20	98.94	89.48	96.91	80.65	94.00	97.94	99.48	92.23	97.84	84.26	95.54	98.86	99.71	94.51	98.66	87.43	96.78	C
	96.15	98.93	89.24	96.84	81.04	94.03	97.74	99.44	91.83	97.74	84.77	95.52	98.78	99.67	94.01	98.54	88.02	96.83	E
12	96.35	99.00	89.42	96.90	79.70	93.54	97.62	99.43	91.68	97.67	82.97	94.88	98.62	99.62	93.63	98.39	85.87	96.08	C
	96.79	99.11	90.56	97.25	82.64	94.61	98.11	99.53	92.75	97.98	85.69	95.81	99.00	99.73	94.62	98.66	88.39	96.89	E
14	96.43	99.01	90.81	97.39	81.18	94.17	97.60	99.39	92.56	98.03	83.83	95.28	98.54	99.65	94.11	98.58	86.23	96.26	C
	96.42	99.01	91.68	97.64	82.83	94.73	97.52	99.37	93.38	98.25	85.41	95.76	98.41	99.62	94.87	98.77	87.72	96.69	E
16	96.50	99.03	91.20	97.50	81.50	94.20	97.53	99.36	92.74	98.07	83.96	95.16	98.38	99.62	94.11	98.56	86.20	96.06	C
	96.45	99.01	92.55	97.89	82.75	94.63	97.54	99.34	94.05	98.42	85.17	95.54	98.42	99.63	95.37	98.88	87.36	96.38	E

C – circular cross-section (*Junior – Irritec, Italy*); E – elliptic cross-section (*DP Line (D5) – Irritec, Italy*).

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$U_C^{ABS} = \frac{q_{min}}{q_{max}}.100$ – coefficient of absolute uniformity; $U_C^{CHR} = \left[1 - \frac{\frac{1}{n}\sum_{i=1}^{n}\left|q_i - \bar{q}\right|}{\bar{q}}\right].100$ – Christiansen uniformity coefficient.

5. COMPARATIVE ANALYSIS OF THE INVESTIGATION RESULTS

According to the above mentioned, it could be expected that with the pipes with elliptic cross section the head losses along the laterals length will be heavier but the results indicate the opposite – the losses with the elliptic cross section are lighter and close to the ones with drip laterals with circular cross section. The main reason for this is the comparatively lighter minor head losses with the elliptic type due to the much smaller water-stopping area of the flat type drippers.

According to the design methods for drip irrigation systems [2] and [8], from the beginning to the middle of the drip lateral are realized about 75% of the total loss of head in the whole lateral, while the test results indicate that this percentage is about 85% which is connected with the determination of the operating head in the whole irrigation battery during the design.

The comparison of the so obtained uniformity coefficients indicates that in case of zero slope of the terrain, the increase of the operating head leads to insignificant increase of the two uniformity coefficients for all lengths, and the values according to Christiansen are much higher compared to those of the absolute uniformity and reach very high percent – 96-98%. With the terrain slope of 1 % both uniformity coefficients have very high values - 97-98% for lengths 40 and 60 m, while for 80 m are smaller (over 81 %), which is due on one hand to the behavior of the head line, and on the other hand, to the additional head due to the geodetic terrain level difference. Besides, it should be noted that the differences in the uniformity coefficients in the two types of pipe are very small.

In the 2% terrain slope, the uniformity coefficients are higher than the ones with 1% for both pipe types, the highest being with the smaller lengths – 40 and 60 m, which indicates that after those lengths the additional head from the terrain level difference has a negative effect.

6. BASIC INFERENCES AND CONCLUSIONS

- The hydraulic head losses in the drip laterals with elliptic cross section are smaller and close to those with circular cross section.
- The values of the absolute uniformity coefficient and those of the coefficient according to Christiansen for the smaller lengths – 40-60 m are approximately equal for both pipe types.
- The increase of the operating pressure from 6 to 16 m in case of horizontal terrain, for both pipe types, leads to insignificant increase of the uniformity coefficients.

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