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Full Length Research Paper

A research on determining the friction losses formed in the small diameter floppy polythene pipe lines

Abdullah Kadayifci[1], Gokhan Ismail Tuylu[2], Ulas Senyigit[1]* and Hasan Oz[3]

[1]University of Süleyman Demirel, College of Agriculture, Isparta-Turkey.
[2]University of Ege, College of Agriculture, İzmir-Turkey.
[3]University of Süleyman Demirel, College of Agriculture, Isparta-Turkey.

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In pressured irrigation systems, water flowing in pipes is stable from the point of view of the hydraulic and it gradually decrease through the pipe lines. In sprinkler irrigation systems, sprinkler head pressure through the pipe line is different due to friction and local losses formed in parts of the pipes between sequent sprinkler heads and the differences resulting from slope. Generally, sprinkler head pressure has a maximum level in the beginning of lateral pipe lines and a minimum level in the end of lateral pipe lines. The velocity of water flow in the pipe line, the diameter and length of the pipe and the friction loses formed as a result of roughness inside the pipe should be known for a good design. The easiest and fastest way is to make use of the values given in the tables or diagrams determined by the equation of Hazen-Williams. However, no data related to floppy polythene (PE) pipes with small diameter is available in the tables and diagrams mentioned. In this study, values relating to friction losses and pressures formed in 10, 20, 30,…, 100 m through the pipe for the without slope in different velocity (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 m s^{-1}) and water flow have been measured and it was found that connection between them using floppy PE pipes (6 bar) with small diameter (Ø20, 25, 32, 40 and 50) have been produced by some plastic companies in Turkey and particularly used in the irrigation systems in landscape areas. In conclusion, it was stated by the people who worked on the experiment that the parameters obtained could be used.

Key words: Friction losses, polythene (PE) pipes, irrigation system.

INTRODUCTION

In sprinkler irrigation systems, sprinkler head pressure along the pipe line is different from each other due to friction losses formed in pipe sections among sequent sprinkler heads and the difference of height caused by slope. Generally, head pressure has the highest value at the beginning of the lateral and the lowest value at the end of the lateral (Yıldırım, 2003).

In the process of design of sprinkler irrigation systems after lateral pipe diameter was determined, head pressure in the beginning of lateral, the pressure of lateral inlet and the pressure values expected in the main pipe line were calculated (Yıldırım, 2003). Thus, in the equation, h_f symbolizes friction losses formed in the sections of the pipe considered. The easiest and fastest way of calculating this parameter is to use the Tables or diagrams developed by means of the equation of Hazen-Williams. In these Tables or diagrams it seems that friction losses resulted from the function of four factors. These are the velocity of water flow in the pipe line, pipe diameter, pipe length and roughness of inside the pipe (Rochester, 1995).

However, in the Tables and diagrams mentioned, steel, asbestos cement, PVC and friction losses formed in strong polythene (PE) pipes were available (Anonymous, 1988). On the other hand, nowadays floppy pipes with small diameter which can be bent according to the shape of the area have been used in some parts of fixed sprinkler irrigation systems in which pop-up sprinkler heads were used especially to irrigate landscapes areas (Rochester, 1995). The tables and diagrams mentioned cannot be used to design irrigation systems using floppy polythene (PE) pipes with small diameters.

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*Corresponding author. E-mail: ulassenyigit@hotmail.com.

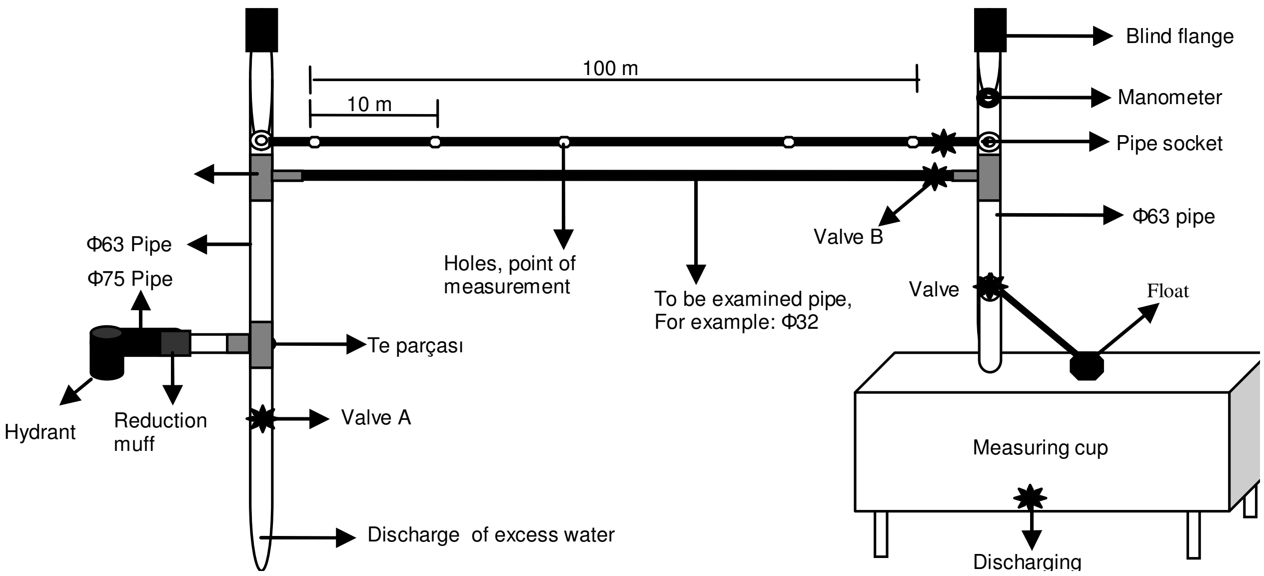

Figure 1. The measuring mechanism.

In addition, in the catalogue presented by the companies producing them, these were not satisfactory although some data relating to friction losses formed under different pressure (Anonymous 1993, 1995 and 2007). In pressured irrigation systems, the water flow in the pipes is stable from the point of hydraulic and follows a pro-gress which is reducing along the pipe lines. The distribution of pressure formed in the irrigation pipes are controlled by the reduction of energy resulted by the friction in the pipe mentioned and the energy which was lost or obtained relates to the natural slope of the pipe (Tüzel, 1990). To determine friction losses along the lateral, it is accepted that the conditions of turbulent flow are formed in the environment in which the water flow of nozzle or sprinkler heads is generally equal and smooth from the point of view of the hydraulic (Wu et al., 1979). However, important differences between the equations Hazen-Williams and Darcy-Weisbach commonly used and the results obtained in the same conditions were figured out since both the water flow of nozzle or sprinkler heads change as a result of friction losses and the parts of nozzles or sprinkler heads inside the pipe cause an increase of friction loss (Korukcu, 1980). Moreover, the value of water flow also changes because of the cross-sectional area of flow and roughness along the lateral change. Thus, it is necessary to determine friction losses related to laterals produced or planned for irrigation systems and obtain equations of friction loss based on these results in laboratoeries (Bezdek and Solomon, 1978). Recently, in our country, irrigation pipes and other additional components which have been produced for irrigation systems are varied. However, the researches made to determine the technical characteristics of pipes and system components are not sufficient. No research has been made on floppy polythene (PE) pipe with small diameter.

Thus, in this study presented, to be able to make people using the components obtain correct information and complete the deficiency in the topic mentioned and contribute to the studies related to this topic, values related to friction losses and pressures formed in 10,20,30,..,100 m through the pipe for the conditions without slope in different velocity (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 m s^{-1}) and water flow have been measured and found out the connection between them using floppy polythene (PE) pipes (6 bar) with small diameter (Ø20, Ø25, Ø32, Ø40 and Ø50) which have been produced in our country.

MATERIALS AND METHODS

To determined the values of friction loss (h_f) (resulted by friction) formed in floppy PE pipes with small diameter commonly used to irrigate particularly landscapes areas, the measuring mechanism given in Figure 1 was prepared in the University of Suleyman Demirel-Turkey, in 2007.

In the prepared measuring mechanism, the water for the system was supplied by a hydrant being in the campus of the university. The hydrant having an outlet with Ø75 supplies water with maximum 7.6 L s^{-1}. The outlet of the hydrant was fixed to PVC lateral pipe with Ø63 by means of reduction muff and Te-fitting. The end of this pipe was closed with a blind plug and a valve (valve A) was fixed to the other end of this pipe. This valve (valve A) was used to regulate the water flowing, velocity and pressure delivered to the system formed the system. Outlets with different diameters (Ø63x20, Ø63x25 and Ø63x32) to fix the pipes with Ø20, Ø25 and Ø32 on the PVC pipe with Ø63 and reduction Te-fittings (Ø63x 40x63 and Ø63x50x63) to fix the pipes with Ø40 and Ø50 were placed. The pipes examined during the measurement were fixed to them. In the experimentation, the water was only delivered to the pipe examined; the other outlets on the pipe with Ø63 were kept closed by a blind plug. Holes with small diameters were formed at each 10 m (10, 20, 30, 100 m) on the pipes examined. These holes

Table 1. Floppy PE pipes examined in the study, water flow (Q) and the time period of fulfilling the measuring cup (T).

V $m\ s^{-1}$	Φ20		Φ25		Φ32		Φ40		Φ50	
	$D_{iç}$, 16 mm		$D_{iç}$, 20 mm		$D_{iç}$, 25 mm		$D_{iç}$, 32 mm		$D_{iç}$, 40 mm	
	Q, $L\ s^{-1}$	T, s	Q, $L\ s^{-1}$	T, s	Q, $L\ s^{-1}$	T, s	Q, $L\ s^{-1}$	T, s	Q, $L\ s^{-1}$	T, s
0.5	0.10	800	0.16	516	0.25	327	0.40	200	0.63	127
1.0	0.20	400	0.31	258	0.49	163	0.80	100	1.26	63
1.5	0.30	267	0.47	172	0.74	109	1.20	67	1.89	42
2.0	0.40	200	0.62	129	0.98	82	1.60	50	2.52	32
2.5	0.50	160	0.78	103	1.23	65	2.00	40	3.15	25
3.0	0.60	133	0.93	86	1.47	54	2.40	33	3.78	21

were kept closed with blind on-line nozzle (injected into silicon) when there was no measurement. To regulate the velocity of water flow, one valve (valve B) was fixed to the end of each pipe examined (approximately 1 m after the last measure point). A piece of pipe which was 1 m length and with the same diameter was fixed to this valve; they were also fixed to a PVC pipe with Ø63 by using suitable outlets and reduction Te-fitting. To be able to regulate the pressure formed here a manometer was placed on the pipe with Ø63. A cup having a certain volume and seen in Figure 1 and a valve which could be closed with a float according to the water level in the cup were fixed in the outlet of this pipe Ø63. Measuring cup was made with aluminum and was in size of 50x40x40 cm (80 L) and a valve and an outlet were fixed to its bottom to water flow.

In the experiment, the conditions in which the velocity of water flow in the pipes was approximately 0.5, 1, 1.5, 2, 2.5 and 3 m s^{-1} were examined since it was aimed to determine the change of pressure formed in different level of water flow in different horizontal distances. To determine this, the time period which the water flowing in the pipes fills the measuring cup was calculated. For this purpose, the valves (in point A and point B) mentioned were regulated by trial and error. Thus, the volume of discharge in the pipe was measured with chronometer and the measuring cup and the measured value was reviewed as equation of continuity (Equation 1). And cross section of water flow was calculated using equation 2.

$$Q = A\,V \qquad (1)$$

$$A = \pi D^2 / 4 \qquad (2)$$

Where; Q is water flow ($m^3\ s^{-1}$), A is cross sectional area of pipe, (m^2) and V is velocity of water flow (m s^{-1}) and D is pipe inner diameter (m).

In the experimentation, the pressures formed in different horizontal distances in the pipes (in the holes formed at each 10 m on the pipes) examined, was measured with Keller Leo 3 digital manometer by keeping the velocity of water in different levels (by keeping the valve at the bottom of the cup open and by keeping the velocity and discharge of water flow in the system stable). At this stage, it was considered that the value of manometer placed on PVC pipe Ø63 at the end of the system was nearly between 2 - 3 bars, so it was tried to obtain the pressure value which sprinkler heads produced in the market could work in the last outlet. However, it was figured out that no pressure was formed in the first points since a great deal of friction losses formed in the pipes with small diameters when the velocity of flow was high during the measurement. Thus, the pressure mentioned was increased as much as possible.

The place in which the experimentation performed was leveled by being measured by means of surveyor's level so that no difference of height would form between the initial and final points in the system.

During the measurements the heat of the water which was studied in the experiment was constantly observed and measured. It was on average 23 - 25^{0}C.

In the study, the measurements were presented in the floppy polythene (PE) pipes with small diameter produced by some plastic companies in Turkey. The values of inner diameter, volume and the period of fulfilling the cup at similar levels of velocity related to them are given in Table 1.

RESULTS AND DISCUSSION

In the floppy polythene (PE) pipes (6 bar) with small diameter (Ø20, Ø25, Ø32, Ø40 and Ø50) produced by some plastic companies in Turkey and particularly used to irrigate landscape areas, the values related to fiction loss (due to friction) and pressure formed in 10, 20, 30, …100 m of the pipe line in the area without slope, at different velocity (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 m s^{-1}) and water flow are given in Table 2. The average values of pressure and friction loss are given in the Table since no much difference was observed between the values of pressure measured in the pipes which were in the same size and which were produced by different plastic companies. The values h_f in the Table was calculated according to the values of pressure measured in different points on the pipe line and the valve h_f was given as 0 (zero) in the initial point.

The values related to friction losses formed in 100 m in different velocity in the pipe lines are given Figures 2 - 6.

When the figures mentioned were examined, it will be seen that there are logarithmical relationships which are quite high (R^2 = 0.97 - 1.00) between the volume and friction loss in the diameters of all pipes. The values h_f formed in the floppy PE pipes with different small diameter due to the water flow (Q) and horizontal length of pipe (L) could be calculated by means of the equations given below.

$$h_f = 1{,}481\,Q^{1{,}86}\,L \quad \text{for pipe diameter Ø20} \qquad (3)$$

$$h_f = 0{,}568\,Q^{1{,}84}\,L \quad \text{for pipe diameter Ø25} \qquad (4)$$

$$h_f = 0{,}196\,Q^{1{,}87}\,L \quad \text{for pipe diameter Ø32} \qquad (5)$$

Table 2. The values of velocity (V), water flow (Q), pressure (P) and friction losses (h_f) in the pipesnexamined in different horizontal distances.

	Φ20				Φ25				Φ32				Φ40				Φ50			
L m	V ms^{-1}	Q L/s	P bar	h_f m	V ms^{-1}	Q L/s	P bar	h_f m	V ms^{-1}	Q L/s	P bar	h_f m	V ms^{-1}	Q L/s	P bar	h_f m	V ms^{-1}	Q L/s	P bar	h_f m
0	0.51	0.102	2.130	0.00	0.49	0.152	2.160	0.00	0.50	0.245	2.035	0.00	0.52	0.416	2.150	0.00	0.49	0.617	2.210	0.00
10			2.154	0.24			2.179	0.19			2.052	0.17			2.162	0.12			2.219	0.09
20			2.203	0.49			2.219	0.40			2.084	0.32			2.188	0.26			2.238	0.19
30			2.277	0.74			2.278	0.59			2.132	0.48			2.226	0.38			2.266	0.28
40			2.376	0.99			2.356	0.78			2.197	0.65			2.277	0.51			2.304	0.38
50			2.499	1.23			2.453	0.97			2.277	0.80			2.340	0.63			2.351	0.47
60			2.646	1.47			2.571	1.18			2.373	0.96			2.417	0.77			2.408	0.57
70			2.818	1.72			2.708	1.37			2.484	1.11			2.506	0.89			2.474	0.66
80			3.014	1.96			2.864	1.56			2.612	1.28			2.607	1.01			2.550	0.76
90			3.458	2.22			3.040	1.76			2.756	1.44			2.722	1.15			2.635	0.85
100			3.704	2.46			3.235	1.95			2.915	1.59			2.849	1.27			2.730	0.95
0	0.98	0.196	1.523	0.00	0.99	0.307	1.815	0.00	0.98	0.480	1.835	0.00	1.01	0.808	1.899	0.00	1.00	1.260	2.135	0.00
10			1.585	0.62			1.869	0.54			1.876	0.42			1.938	0.39			2.167	0.32
20			1.648	1.25			1.922	1.07			1.918	0.83			1.978	0.79			2.199	0.65
30			1.710	1.87			1.976	1.61			1.959	1.25			2.017	1.18			2.232	0.97
40			1.773	2.50			2.029	2.14			2.001	1.66			2.056	1.58			2.264	1.29
50			1.835	3.12			2.083	2.68			2.042	2.08			2.096	1.97			2.296	1.62
60			1.897	3.74			2.137	3.21			2.084	2.49			2.135	2.36			2.329	1.94
70			1.960	4.37			2.190	3.75			2.125	2.91			2.175	2.76			2.361	2.26
80			2.022	4.99			2.244	4.29			2.167	3.32			2.214	3.15			2.393	2.59
90			2.085	5.62			2.297	4.82			2.208	3.74			2.253	3.55			2.426	2.91
100			2.147	6.24			2.351	5.36			2.250	4.15			2.293	3.94			2.458	3.23
0	1.48	0.296	1.023	0.00	1.52	0.471	1.023	0.00	1.50	0.735	1.411	0.00	1.48	1.184	1.588	0.00	1.51	1.903	1.567	0.00
10			1.145	1.22			1.167	1.44			1.517	1.06			1.670	0.82			1.643	0.77
20			1.267	2.43			1.312	2.89			1.624	2.13			1.752	1.64			1.720	1.53
30			1.388	3.65			1.456	4.33			1.730	3.19			1.834	2.46			1.796	2.30
40			1.510	4.86			1.600	5.77			1.836	4.26			1.916	3.28			1.873	3.06
50			1.631	6.08			1.745	7.22			1.943	5.32			1.998	4.10			1.949	3.83
60			1.753	7.30			1.889	8.66			2.049	6.38			2.080	4.92			2.026	4.59
70			1.875	8.51			2.033	10.10			2.156	7.45			2.162	5.74			2.102	5.36
80			1.996	9.73			2.178	11.55			2.262	8.51			2.244	6.56			2.179	6.12
90			2.118	10.95			2.322	12.99			2.368	9.58			2.326	7.38			2.256	6.89
100			2.240	12.16			2.466	14.43			2.475	10.64			2.408	8.20			2.332	7.65
0	2.01	0.402	0.135	0.00	2.04	0.632	0.209	0.00	2.06	1.009	0.400	0.00	1.96	1.568	0.755	0.00	1.98	2.495	1.312	0.00
10			0.394	2.58			0.453	2.44			0.614	2.14			0.909	1.53			1.431	1.18
20			0.652	5.16			0.698	4.89			0.828	4.28			1.062	3.07			1.549	2.37
30			0.910	7.75			0.942	7.33			1.042	6.42			1.216	4.60			1.667	3.55
40			1.168	10.33			1.187	9.78			1.256	8.56			1.369	6.14			1.785	4.73
50			1.426	12.91			1.431	12.22			1.470	10.70			1.522	7.67			1.904	5.91
60			1.685	15.49			1.676	14.67			1.684	12.84			1.676	9.20			2.022	7.10
70			1.943	18.07			1.920	17.11			1.898	14.98			1.829	10.74			2.140	8.28
80			2.201	20.66			2.165	19.56			2.112	17.12			1.982	12.27			2.258	9.46
90			2.459	23.24			2.409	22.00			2.325	19.26			2.136	13.80			2.377	10.64
100			2.717	25.82			2.654	24.45			2.539	21.40			2.289	15.34			2.495	11.83

Table 2. Continue.

	Φ20				Φ25				Φ32				Φ40				Φ50			
L m	V ms^{-1}	Q L/s	P bar	h$_f$ m	V ms^{-1}	Q L/s	P bar	h$_f$ m	V ms^{-1}	Q L/s	P bar	h$_f$ m	V ms^{-1}	Q L/s	P bar	h$_f$ m	V ms^{-1}	Q L/s	P bar	h$_f$ m
0	2.46	0.492	0.066	0.00	2.54	0.787	0.123	0.00	2.60	1.274	0.268	0.00	2.45	1.960	0.278	0.00	2.53	3.188	0.845	0.00
10			0.574	5.08			0.514	3.91			0.583	3.16			0.511	2.33			1.007	1.63
20			1.082	10.17			0.905	7.81			0.899	6.32			0.745	4.67			1.170	3.26
30			1.591	15.25			1.295	11.72			1.215	9.48			0.978	7.00			1.333	4.89
40			2.099	20.33			1.686	15.62			1.531	12.64			1.212	9.34			1.496	6.52
50			2.607	25.42			2.076	19.53			1.847	15.80			1.445	11.67			1.659	8.14
60			3.116	30.50			2.467	23.44			2.163	18.96			1.679	14.01			1.822	9.77
70			3.624	35.58			2.858	27.34			2.479	22.12			1.912	16.34			1.985	11.40
80			4.132	40.67			3.248	31.25			2.795	25.28			2.145	18.68			2.148	13.03
90			4.641	45.75			3.639	35.15			3.111	28.43			2.379	21.01			2.311	14.66
100			5.149	50.83			4.029	39.06			3.427	31.59			2.612	23.35			2.473	16.29
0	No measurement was performed since the attachments where the pipes were fixed to each other was broken and fallen off due to over pressure formed in the system.								2.89	1.416	0.131	0.00	2.98	2.384	0.325	0.00	2.95	3.717	0.214	0.00
10											0.512	3.81			0.631	3.06			0.476	2.63
20											0.893	7.62			0.936	6.11			0.739	5.25
30											1.274	11.43			1.242	9.17			1.001	7.88
40											1.655	15.24			1.548	12.23			1.264	10.50
50											2.036	19.05			1.854	15.29			1.526	13.13
60											2.417	22.86			2.159	18.34			1.789	15.75
70											2.798	26.67			2.465	21.40			2.051	18.38
80											3.179	30.48			2.771	24.46			2.314	21.00
90											3.560	34.29			3.076	27.52			2.576	23.63
100											3.941	38.10			3.382	30.57			2.839	26.25

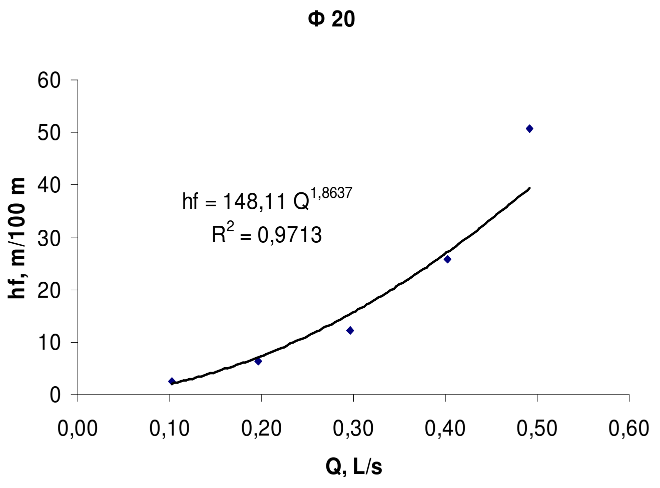

Figure 2. h$_f$ values in the Φ20 PE pipes.

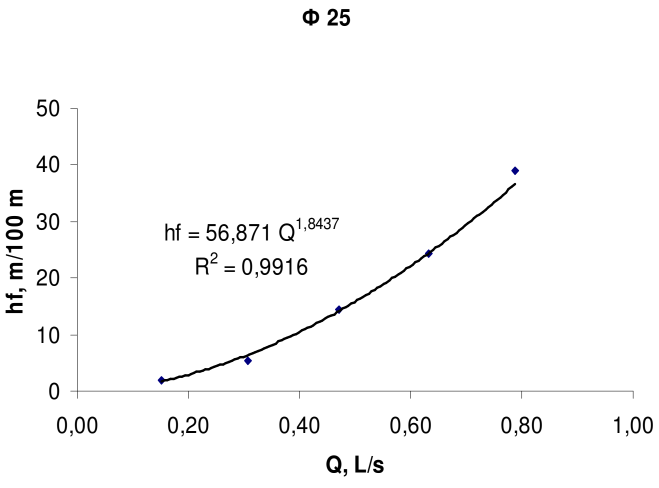

Figure 3. h$_f$ values in the Φ25 PE pipes.

$h_f = 0,063\ Q^{1,87}\ L$ for pipe diameter Ø40 (6)

$h_f = 0,022\ Q^{1,81}\ L$ for pipe diameter Ø50 (7)

Especially in irrigation areas, the model Darcy-Weisbach and the equation Hazen-Williams are more outstanding when the studies are related to friction loss formed in the pipes. The model Darcy-Weisbach was developed to predict friction loss related to velocity of water flow (V) and inner diameter (D) in a horizontal L pipe and has a form

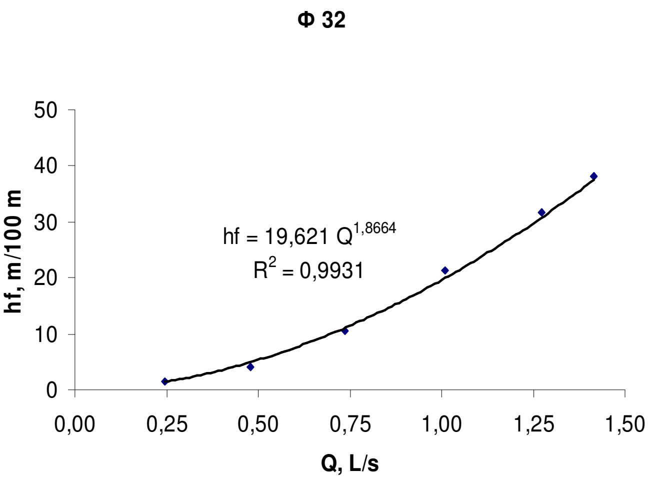

Figure 4. h_f values in the Φ32 PE pipes.

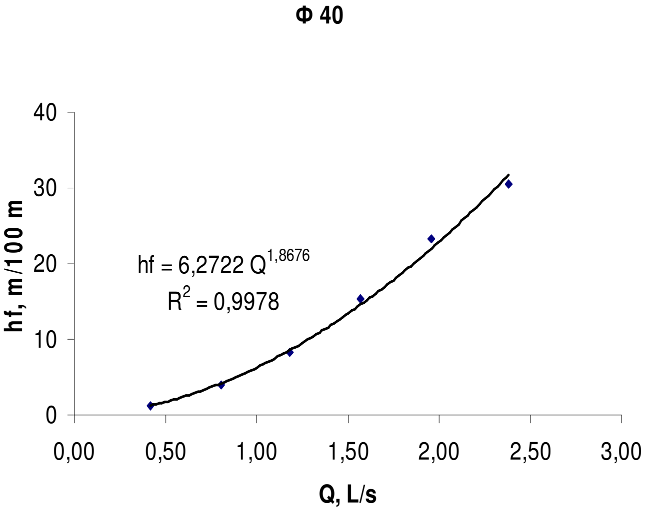

Figure 5. h_f values in the Φ40 PE pipes.

obtained as a result of a careful study. It was described as in the below equation (Equation 8) (Howell et al., 1983).

$$h_f = 4f\,(L/D)\,(V^2/2g) \tag{8}$$

However, the equation Hazel-Williams has the form given in the below equation (Equation 9) (for c, friction coefficient is 150).

$$h_f = 1.135\ 10^6\,(Q^{1.852}/D^{4.871}) \tag{9}$$

Generally, the friction loss formed related to the water flow in the pipes can be written in a simple way as shown below equation (Equation 10).

$$h_f = a\,Q^m\,L \tag{10}$$

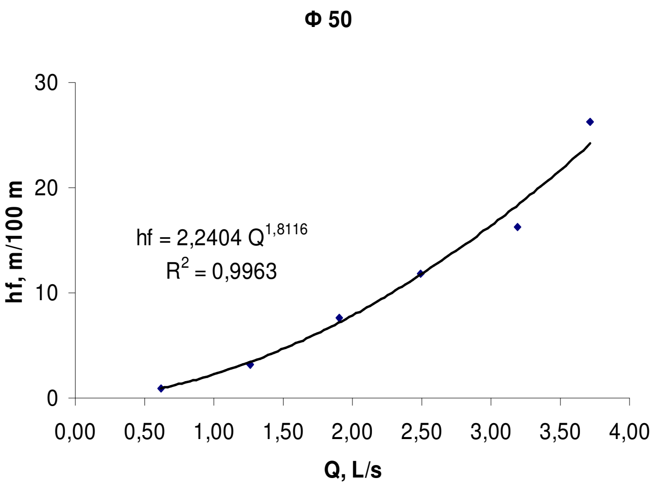

Figure 6. h_f values in the Φ50 PE pipes.

where; h_f is friction loss (m), f and c is friction coefficients, L is length of pipe (m) is exponential coefficient (1 for laminar flow, 1.852 for turbulent flow, 2 for full-turbulent flow) and g is gravitational acceleration ($m^2\ s^{-1}$).
As it is seen in the equations above, friction losses in the pipes were developed to make general predictions which will be able to include the variables affecting the event and theoretically velocity (V) and water flow (Q) has exponential variation.

As a result of this study, the equations were determined in the floppy PE pipes with small diameter (Ø20, 25, 32, 40 and 50) similar to the model "$h_f = a\,Q^m\,L$" given in the equation 10 mentioned above whose data was not available in the Tables and diagrams determined by the equation of Hazen-Williams. These equations showed that the relationships obtained experimentally in this study can be use practically and reliably by the people working on the topic.

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