How can identify sensitivity of hydraulic characteristics of irrigation systems?

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Abstract— *Due to the benefits of center pivot irrigation system into the other techniques, especially surface irrigation, more accurate design of these systems for saving in water resources, increasing irrigation efficiency, and finally encourage farmers to use of this system (when using this method is economical), recognition of effective parameters on center pivot have a great importance. In this study, using PipeLoss software, amounts of pressure loss, friction slope, inflow velocity, velocity head, and Reynolds number in center pivot systems survived. The results showed that: Pipe inside diameter was more effective than other parameters. Changes of pressure loss, in all cases (except* Q_s*), were the maximum. Changes of velocity head were the maximum in scenarios related to the changes of system discharge. In center pivot system design, should be noted to pipe inside diameter and system discharge as input and pressure loss as output, more than other inputs and outputs parameters.*

Keywords— pressurized irrigation, hydraulic properties, irrigation system design.

I. INTRODUCTION

Study of center pivot irrigation has always desired for researchers, which some of them will be described in the following.

King and Kincaid [1] researched optimal performance from center pivot sprinkler systems. They proposed that low-pressure spray sprinklers could replace the original high-pressure impact sprinklers. Smith [2] evaluated a center pivot irrigation system successfully. Omary et al. [3] developed a multiple-segment water application system and attached to a commercial center pivot irrigation system to provide variable application depths within each segment at a given speed. The laboratory and simulation results showed high application uniformity (Christiansen coefficient of uniformity was greater than 90%). Porter and Marek [4] studied relationship between center pivot sprinkler application depth and soil water holding capacity. They expressed that the key to optimizing center pivot irrigation was management, which takes into account changing crop water requirements and the soil's permeability and water holding capacities. Vories et al. [5] studied performance of a variable rate center pivot system. Analytical equations for friction correction factors for center-pivot laterals developed [6, 7, 8]. In other studies hydraulics of center pivot laterals analyzed [9, 10, 11, 12, 13, 14]. Peters and Evett [15] automated a center pivot was completely using the temperature-time-threshold method of irrigation scheduling. The automatic irrigation system has the potential to simplify management, while maintaining the yields of intensely managed irrigation. Mohamoud et al. [16] optimized center pivot irrigation system design with tillage effects. Spare et al. [17] analyzed field performance of center pivot sprinkler packages. Gilley [18] investigated suitability of reduced pressure center pivots. The results could be used as a general guide to determine if a particular system may have a runoff problem under a given situation. A distributional semiempirical model for the simulation of spatial distribution of water application under center pivot sprinklers developed [19, 20] This simulation model of spatial water distribution under sprinklers of center pivot could be used to simulate the distribution of water under a typical pivot machine. Yan et al. [21] characterized center pivot irrigation with fixed spray plate sprinklers. Reducing the percent-time cycle time from 60 s to 40 s resulted in a slight increase in the radial uniformity coefficients, with an average of 1.09% to 1.17%, while there was no significant influence on the circular uniformity coefficients. Dukes and Perry [22] tested uniformity of variable-rate center pivot irrigation control systems. The variable-rate technologies tested under the conditions presented in this paper had at least as good uniformity as the center pivot and linear move systems when functioning in non-variable-rate mode. Marjang et al. [23] analyzed center pivot uniformity with variable container spacing. Silva [24] fitted infiltration equations to center pivot irrigation data in a Mediterranean soil. Delirhasannia et al. [25] presented a dynamic model for water application using center pivot irrigation. Valín et al. [26] presented a model for center pivot design and evaluation. Abo-Ghobar [27] studied losses from low-pressure center pivot irrigation systems in a desert climate as affected by nozzle height. Heermann et al. [28] presented An accurate analysis of irrigation systems plays an impotant role in agricultural water management [29-

45]. user-friendly software for an integrated water-energy management system for center pivot irrigation. In this study, using PipeLoss software, amounts of pressure loss, friction slope, inflow velocity, velocity head, and Reynolds number in center pivot systems survived.

II. MATERIALS AND METHODS

Number of six parameters include pipe friction factor (C), inside diameters of pipe (ID), lengths of pipe (L), number of equally-spaced outlets (N_s), total flow into the pipe (Q_s), and discharge of end gun (Q_g) was selected for scrutiny of pressure loss, friction slope, inflow velocity, velocity head, and Reynolds number in center pivot systems. For this purpose by choosing ten different scenarios and using PipeLoss software, sensitivity of mentioned parameters investigated. All of the scenarios were in a reasonable range. In most cases initial data were average of own range and almost in most projects, these amounts is selected for center pivot irrigation system. Increase or decrease for each scenario was based on actual values for example amounts of inside diameters were one of these values: 2, 2.5, 3, 4, 6, 8, 10, 12, 14, 15 inches. However, inside diameters less than 4 inches maybe not used in a real project, in this study was used for compared with other values. Recommended formulas based on pipe material are as follows:

$$AID=AOD-2(MWT+0.5WTT) \quad (1)$$

$$2S/P=SDR-1 \quad (2)$$

$$2S/P=SDR+1 \quad (3)$$

Where *AID* is average inside diameter (in), *AOD* is average outside diameter (in), *MWT* is minimum wall thickness (in), *WTT* is wall thickness tolerance (in), *S* is hydrostatic design stress (lb/in^2), *P* is pressure rating (lb/in^2), and *SDR* is standard thermoplastic dimension ratio as follows:

$$SDR=AOD/MWT \quad (4)$$

$$SDR=AID/MWT \quad (5)$$

Equation (1) is used for PVC IPS (Iron Pipe Size) and PVC PIP (Plastic Irrigation Pipe), equations (2) and (4) are used for PVC, ABS and PE pipe with outside diameter controlled, and equations (3) and (5) are used for PE pipe with inside diameter controlled.

Table 1 shows initial input and output data in this study.

Table.1: Values of initial input and output

Input	C	ID (mm)	L (m)	N_s	Q_s (l/s)	Q_g (l/s)
	150	151.6	400	25	50	8
Output	Pressure loss (kPa)	Friction slope (kPa/m)	Velocity in pipe (m/s)	Velocity head (kPa)	Reynolds number (20°C)	
	90.92	0.373	2.77	3.835	417836	

III. RESULTS AND DISCUSSION

Table 2 shows scenarios related to the pipe

Table.2: Scenarios related to the pipe friction factor

C	Pressure loss (kPa)	Δ (%)	Friction slope (kPa/m)	Δ (%)	Velocity in pipe (m/s)	Δ (%)	Velocity head (kPa)	Δ (%)	Reynolds number (20°C)	Δ (%)
100	192.51	112	0.790	112	2.77	0	3.835	0	417836	0
110	161.39	78	0.663	78	2.77	0	3.835	0	417836	0
115	148.65	63	0.610	64	2.77	0	3.835	0	417836	0
120	137.39	51	0.564	51	2.77	0	3.835	0	417836	0
125	127.40	40	0.523	40	2.77	0	3.835	0	417836	0
130	118.48	30	0.486	30	2.77	0	3.835	0	417836	0
135	110.49	22	0.454	22	2.77	0	3.835	0	417836	0
140	103.30	14	0.424	14	2.77	0	3.835	0	417836	0
145	96.81	6	0.397	6	2.77	0	3.835	0	417836	0
150	90.92	0	0.373	0	2.77	0	3.835	0	417836	0
Average (%)		46		46		0		0		0

According to the Table 2 for decreasing values of pipe friction factor, pressure loss and friction slope increased but values of velocity in pipe, velocity head, and Reynolds number did not change.

Table 3 shows values of pipe inside diameters.

Table.3: Scenarios related to the pipe inside diameters

ID (mm)	Pressure loss (kPa)	Δ (%)	Friction slope (kPa/m)	Δ (%)	Velocity in pipe (m/s)	Δ (%)	Velocity head (kPa)	Δ (%)	Reynolds number (20°C)	Δ (%)
52.5	15828.29	17309	64.988	17323	23.10	734	266.657	6853	1206550	189
62.7	6672.12	7238	27.394	7244	16.20	485	131.075	3318	1010269	142
77.9	2320.56	2452	9.528	2454	10.49	279	55.010	1334	813143	95
101.1	652.76	618	2.680	618	6.23	125	19.390	406	626547	50
151.6	90.92	0	0.373	0	2.77	0	3.835	0	417836	0
201.6	22.72	75	0.093	75	1.57	43	1.226	68	314206	25
252.2	7.64	92	0.031	92	1.00	64	0.501	87	251165	40
302.7	3.14	97	0.013	97	0.69	75	0.241	94	209263	50
353.2	1.48	98	0.006	98	0.51	82	0.130	97	179343	57
378.4	1.06	99	0.004	99	0.44	84	0.099	97	167399	60
Average (%)		3120		3122		219		1373		79

According to the Table 3 decreasing of inside diameter caused increase in all parameters and increasing of inside diameter caused decrease in all parameters. The maximum changes related to the pressure loss and friction slope and the minimum changes related to the Reynolds number.

Table 4 shows different values of pipe lengths.

Table.4: Scenarios related to the values of pipe lengths

L (m)	Pressure loss (kPa)	Δ (%)	Friction slope (kPa/m)	Δ (%)	Velocity in pipe (m/s)	Δ (%)	Velocity head (kPa)	Δ (%)	Reynolds number (20°C)	Δ (%)
60	13.64	85	0.373	0	2.77	0	3.835	0	417836	0
100	22.73	75	0.373	0	2.77	0	3.835	0	417836	0
150	34.10	62	0.373	0	2.77	0	3.835	0	417836	0
200	45.46	50	0.373	0	2.77	0	3.835	0	417836	0
300	68.19	25	0.373	0	2.77	0	3.835	0	417836	0
400	90.92	0	0.373	0	2.77	0	3.835	0	417836	0
500	113.65	25	0.373	0	2.77	0	3.835	0	417836	0
600	136.39	50	0.373	0	2.77	0	3.835	0	417836	0
700	159.12	75	0.373	0	2.77	0	3.835	0	417836	0
800	181.85	100	0.373	0	2.77	0	3.835	0	417836	0
Average (%)		61		0		0		0		0

According to the Table 4 changes of pipe length only were effective on pressure loss. Increasing of *L* increased pressure loss and decreasing of *L* decreased pressure loss.

Table 5 shows different values of number of sprinklers.

Table.5: Scenarios related to the values of number of sprinklers

Ns	Pressure loss (kPa)	Δ (%)	Friction slope (kPa/m)	Δ (%)	Velocity in pipe (m/s)	Δ (%)	Velocity head (kPa)	Δ (%)	Reynolds number (20°C)	Δ (%)
5	98.83	9	0.373	0	2.77	0	3.835	0	417836	0
10	93.72	3	0.373	0	2.77	0	3.835	0	417836	0
15	92.14	1	0.373	0	2.77	0	3.835	0	417836	0
20	91.37	0	0.373	0	2.77	0	3.835	0	417836	0
25	90.92	0	0.373	0	2.77	0	3.835	0	417836	0
30	90.63	0	0.373	0	2.77	0	3.835	0	417836	0
35	90.42	1	0.373	0	2.77	0	3.835	0	417836	0
40	90.26	1	0.373	0	2.77	0	3.835	0	417836	0

45	90.14	1	0.373	0	2.77	0	3.835	0	417836	0
50	90.04	1	0.373	0	2.77	0	3.835	0	417836	0
Average (%)		2		0		0		0		0

According to the Table 5 changes of number of equally-spaced outlets only were effective on pressure loss. Increasing number of sprinklers (N_s) decreased pressure loss and decreasing of N_s increased pressure loss.

Table 6 shows different values system discharges.

Table.6: Scenarios related to the total flow into the pipe

Qs (l/s)	Pressure loss (kPa)	Δ (%)	Friction slope (kPa/m)	Δ (%)	Velocity in pipe (m/s)	Δ (%)	Velocity head (kPa)	Δ (%)	Reynolds number (20°C)	Δ (%)
30	37.51	59	0.145	61	1.66	40	1.381	64	250701	40
35	48.83	46	0.193	48	1.94	30	1.879	51	292485	30
40	61.52	32	0.247	34	2.22	20	2.455	36	334268	20
45	75.56	17	0.307	18	2.49	10	3.107	19	376052	10
50	90.92	0	0.373	0	2.77	0	3.835	0	417836	0
55	107.60	18	0.445	19	3.05	10	4.641	21	459619	10
60	125.56	38	0.523	40	3.32	20	5.523	44	501403	20
65	144.80	59	0.607	63	3.60	30	6.482	69	543186	30
70	165.29	82	0.696	87	3.88	40	7.517	96	584970	40
75	187.03	106	0.790	112	4.16	50	8.629	125	626753	50
Average (%)		51		54		28		58		28

According to the Table 6 the maximum of changes related to the velocity head. For increasing of Q_s values of all parameters increased and for decreasing of Q_s values of all parameters decreased.

Table 7 shows Scenarios related to the end gun discharges.

Table.7: Scenarios related to the end gun discharges

Qg (l/s)	Pressure loss (kPa)	Δ (%)	Friction slope (kPa/m)	Δ (%)	Velocity in pipe (m/s)	Δ (%)	Velocity head (kPa)	Δ (%)	Reynolds number (20°C)	Δ (%)
0	83.60	8	0.373	0	2.77	0	3.835	0	417836	0
2	85.31	6	0.373	0	2.77	0	3.835	0	417836	0
4	87.10	4	0.373	0	2.77	0	3.835	0	417836	0
6	88.97	2	0.373	0	2.77	0	3.835	0	417836	0
8	90.92	0	0.373	0	2.77	0	3.835	0	417836	0
10	92.96	2	0.373	0	2.77	0	3.835	0	417836	0
12	95.07	5	0.373	0	2.77	0	3.835	0	417836	0
14	97.26	7	0.373	0	2.77	0	3.835	0	417836	0
16	99.52	9	0.373	0	2.77	0	3.835	0	417836	0
18	101.87	12	0.373	0	2.77	0	3.835	0	417836	0
Average (%)		6		0		0		0		0

According to the Table 7 changes of Q_g only were effective on pressure loss. Increasing of L increased pressure loss and decreasing of Q_g decreased pressure loss.

Figure 1 shows a compression between all effective parameters in center pivot irrigation systems.

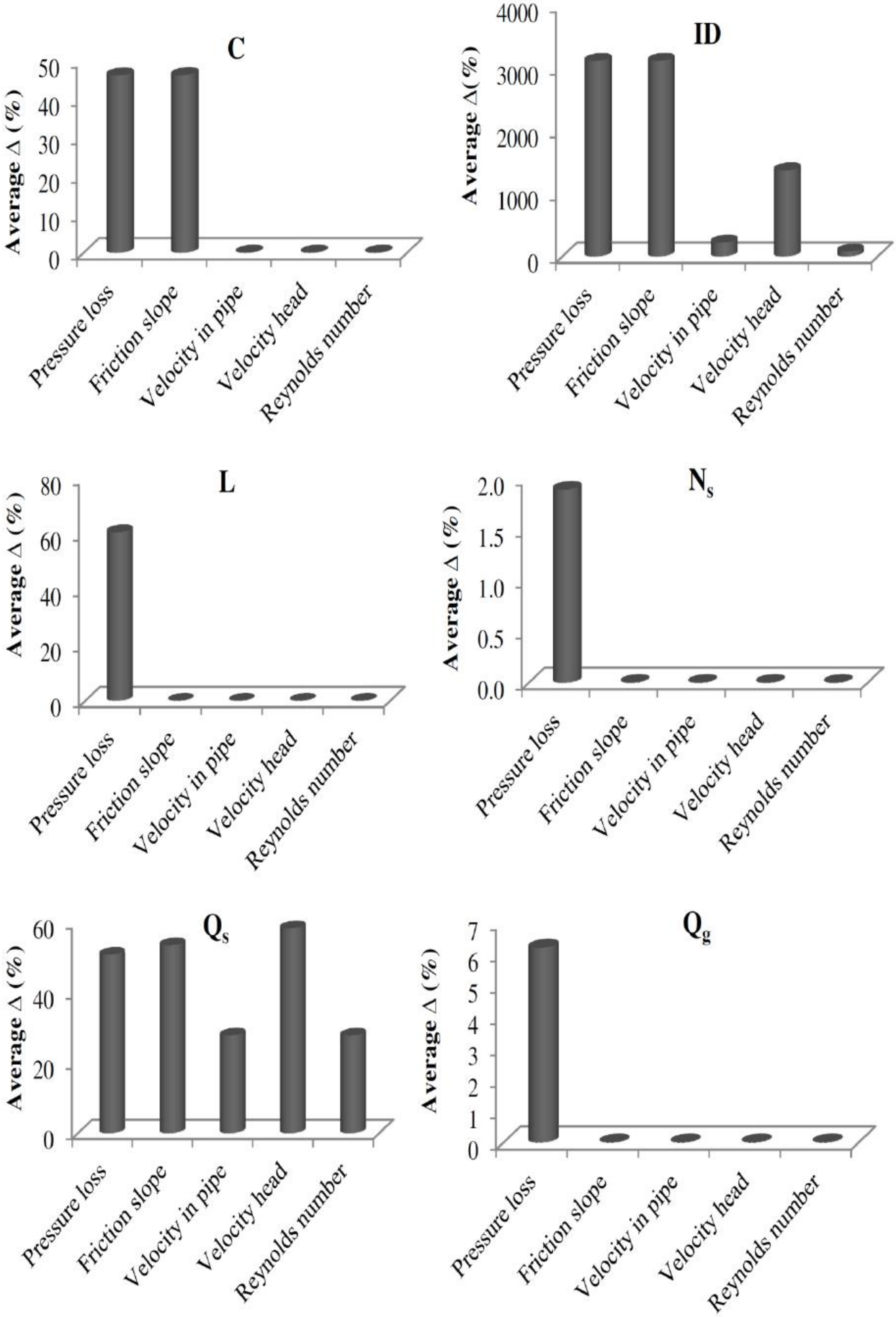

Fig.1: Obtained results for each of six center pivot design parameters

Compression of six center pivot design parameters in Figure 1 showed that pipe inside diameter was more effective than other parameters. Because amounts of changes that caused for increasing or decreasing this parameter, were very more than other parameters. Since pressure loss, was more sensitive than other parameter, changes of pressure loss in all cases (except Q_s) were maximum. Due to the simultaneous and significant impact of system discharge on pressure loss and velocity in pipe, changes of velocity head were the maximum in these states (scenarios related to the changes of system discharge). The amounts of velocity in pipe, velocity head, and Reynolds number were only sensitive to pipe inside diameter and system discharge. The amounts of Reynolds number in all of the states were more than 2000. It shows that there is turbulent flow in center pivot systems.

The mentioned cases shows that in center pivot system design should be noted to pipe inside diameter and system discharge as input and pressure loss as output, more than other inputs and outputs parameters. However, role of other inputs and outputs due to their undeniable effects should not be ignored.

IV. CONCLUSION

Due to the benefits of center pivot irrigation system into the other techniques especially surface irrigation, more accurate design of this systems for saving in water resources, increasing irrigation efficiency, and finally encourage farmers to use of this system (when using this method is economical), recognition of effective parameters on center pivot have a great importance.

In this study, using PipeLoss software, amounts of pressure loss, friction slope, inflow velocity, velocity head, and Reynolds number in center pivot systems survived. The results showed that:

Pipe inside diameter was more effective than other parameters.

Changes of pressure loss in all cases (except Q_s) were the maximum.

Changes of velocity head were the maximum in scenarios related to the changes of system discharge.

In center pivot system design, should be noted to pipe inside diameter and system discharge as input and pressure loss as output, more than other inputs and outputs parameters.

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