Design and testing of device for measuring the longitudinal uniformity of reel hose irrigation machine

Návrh a testovanie zariadenia na meranie pozdĺžnej rovnomernosti pásového zavlažovača

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Abstract

During the cultivation of crops, irrigation is included in necessary working operations like tillage, fertilization and sowing. For irrigation, we require the highest quality of work. Therefore, in this contribution, we focused on monitoring the quality of work of a hose reel irrigation machine. For determining the longitudinal uniformity of winding a hose on a reel, the development of a digital device was necessary. During the development, we had to design its two basic parts – the hardware and software. After construction of the device, its function was tested directly in working conditions of the particular reel hose irrigation machine. The results of our developed device were compared with the results of the Ecostar 4000 (Bauer, Austria) microcomputer, both with the same hose winding speed. On the microcomputer, we set the hose winding speed to +2.1 m*h^{-1}. The average measured value of speed using the first device Speedmeter SM1 (2000, KSVS) was 11.7 m*h^{-1}. The difference between the set and measured speed was 0.4 m*h^{-1} (absolute error of measurement, the relative error of measurement was 3.42 %). In the second case, the measurement was performed using a more modern device – Speedmeter SM2, which allows saving of results into its internal memory (2012, KSVS). The average measured value of winding speed was 12.26 m*h^{-1}, which represents the relative error of measurement 2.77 % compared to the set value of 12.6 m*h^{-1}. Based on the results obtained, we recommend the maintenance of the irrigation machine.

Keywords: hose reel irrigation machine, coefficient of uniformity, quality of work

Abstrakt

Pri pestovaní vybraných plodín sa popri obrábaní pôdy, hnojení a sejbe zaraďuje medzi nevyhnutné pracovné operácie aj zavlažovanie. Pri zavlažovaní však vyžadujeme čo najvyššiu kvalitu práce, preto sme sa v danom článku zamerali na sledovanie kvality práce pásového zavlažovača. Pre zhodnotenie pozdĺžnej rovnomernosti rýchlosti navíjania hadice na cievku bolo treba navrhnúť digitálne zariadenie. Pri zostavovaní meracieho zariadenia bolo potrebné riešiť jeho dve základné časti, návrh hardvérovej a návrh softvérovej časti. Po vyriešení a skonštruovaní zariadenia sa meraním overila jeho funkčnosť priamo v pracovných podmienkach konkrétneho pásového zavlažovača. Navrhnuté digitálne zariadenie sa porovnalo s iným zariadením voči nastavenej rýchlosti navíjania na mikropočítači Ecostar 4000 (Bauer, Austria). Na mikropočítači zavlažovača sme nastavili rýchlosť navíjania hadice na hodnotu 12,1 m*h^{-1}. Priemerná nameraná hodnota prvým zariadením, Speedmeter SM1 (2000, KSVS), bola 11,7 m*h^{-1}. Rozdiel medzi nameranou a nastavenou hodnotou rýchlosti bol 0,4 m*h^{-1} (absolútna chyba merania, relatívna chyba merania bola 3,42 %). V druhom prípade sa merania uskutočnili modernejším – druhým zariadením, Speedmeter SM2, ktoré umožňuje ukladanie údajov do pamäte (2012, KSVS). Priemerná hodnota nameranej pracovnej rýchlosti bola 12,26 m*h^{-1}, čo predstavuje oproti nastavenej hodnote (12,6 m*h^{-1}) relatívnu chybu 2,77 %. Na základe dosiahnutých výsledkov odporúčame vykonať údržbu na závlahovom zariadení.

Kľúčové slová: pásový zavlažovač, koeficient rovnomernosti, kvalita práce

Introduction

The uniformity of spray is an important indicator of the quality of irrigation. The evaluation of the uniformity of spray in terms of the capacity of irrigation system is one of the ways of optimizing the irrigation process (Palková et al., 2012). The capacity of reel hose irrigation machines mainly depends on the speed of hose winding.

Reel hose irrigation machines are designed with a wheeled chassis supported by anchors, on which a reel with a wounded polyethylene hose of diameter 25–140 mm and length 200–600 m is placed (Simoník et al., 2010).

By evaluating the uniformity of spray of the Cipa 600 GX reel hose irrigator according to Christiansen, we obtained the coefficient of uniformity Cu 84.8 %. In that case, the quality of work was reduced by increasing of overlaps. The hose winding speed was controlled by the first measurement device Speedmeter SM1 (Jobbágy et al., 2012).

Foreign authors demonstrate changes in the amount of spray while changing the hose winding speed. The amount of spray depends on the speed of winding the hose on the reel. They had studied the changes using reel hose irrigation machines equipped with Irrigamatic 300 (MAtermacc/Italy) and Rain 9 (Nortoft Electronic/Denmark) microcomputers. An irrigation console had been connected to the reel hose irrigation machine. To measure the uniformity of spray, a square grid of rain gauge vessels with a side length of 1 m was used. When changing the travel speed from 24 m*h^{-1} to 40 m*h^{-1} (section of 1–2 m), the amount of spray was lowered from 28 mm to 16 mm (in the section of 15 m, Al-Karadsheh, 2003). Sourell and Karadsheh (2001) report that the changes in speed from 32 m*h^{-1} to 16 m*h^{-1} occur in the section of 2 m. With this change, the amount of spray also changed from 22 mm to 45 mm (section of 16 m). With another change in speed from 16 m*h^{-1} to 24 m*h^{-1} (section of 1–2 m), the amount of spray changes from 45 mm to 28 mm (section of 11 m) (Sourell and Al-Karadsheh, 2003). As apparent, by increasing the travel speed, the amount of water applied to the section is lowered (Rhoades et al., 1989).

In many contributions, authors focus more on testing the longitudinal uniformity and less on examining the variability of speed of winding the hose on the reel.

Materials and Methods

In Slovakia, reel hose irrigation machines and wide irrigators are among the leading irrigation systems in agriculture. These machines are used for irrigating fields with planted sugar beet, potatoes and other plants. When using reel hose irrigation machines, the amount of spray is controlled by a change in hose winding speed. This is achieved by changing the main gear or by a smooth change in water bypass in the turbine. The change can be performed in two ways – mechanically or digitally with a microcomputer. In field conditions, we have tested the Bauer Tx Rainstar 90/300 reel hose irrigation machine. We developed the first independent device – Speedmeter SM1 at the Department of Machines and Production Systems in 2000 for evaluating the quality of work and longitudinal uniformity. The second measuring device – Speedmeter SM2 is more modern and was developed in 2012 (Fig. 1).

Table 1: Technical parameters of Bauer Rainstar TX Plus 90/300 reel hose irrigation machine

A, mm	B, m	D, m	E, m	F, mm	G, m^3*h^{-1}
90	300	340	76	16–30	17–65
H, MPa	I, kg	J, kg	K, mm	L, mm	M, mm
3.5–10	1,850	3,270	5,350	3,700	3,060

A – diameter of PE tube, B – PE tube length, D – max. length of irrigated strip, E – max. width of irrigation, F – range of nozzle diameter, G – extent of water flow, H – bonding pressure (min. – max.), I – total weight without water, J – total weight with water, K – total length including the machine length, L – length without the irrigation truck, M – total height

Fig. 1: Speedmeter, SM1 and SM2


Fig. 2: Bauer Rainstar 90/300 TX Plus irrigation machine with Ecostar 4000, field measurement

Results and Discussion

The goal of this contribution was to design and develop an independent device for monitoring the speed of winding the hose on the reel – Speedmeter SM2. This device measures the values without a human service (data entering into the memory) and allows the export of measured values to the PC. Other requirements for the device are as follows:

- ability to set the measuring time interval from 1 s to 1,800 s;
- measurement of speed in a range from 0 $m*h^{-1}$ to 40 $m*h^{-1}$;
- ability to set the perimeter of the measuring cylinder on the device in a range from 50 m to 300 m;
- independent power supply from a battery;
- displaying the actual value of hose winding speed.

The design of this device is divided into two main parts:

- hardware,
- software.

Hardware

While designing this part of the device, the ability of storing the measured values into the memory during the whole measuring process was important. The design itself is based on the software of the device. For measuring the speed of hose feed, we used a frame with a tachometer (MOL30, MEGATRON Elektronik, Germany). An incremental rotary encoder transforms the rotary motion to electrical impulses. The transfer of mechanical motion to electrical impulses is performed in a photoelectric contactless way. The technical parameters of this sensor are listed in Table 2.

Table 2: Technical parameter of sensor

Parameter	**Shaft diameter**	**Number of impulses**	**Power supply**	**Protection**
Value	4 mm	1,024 impulse*cyc^{-1}	5 VDC	IP 55

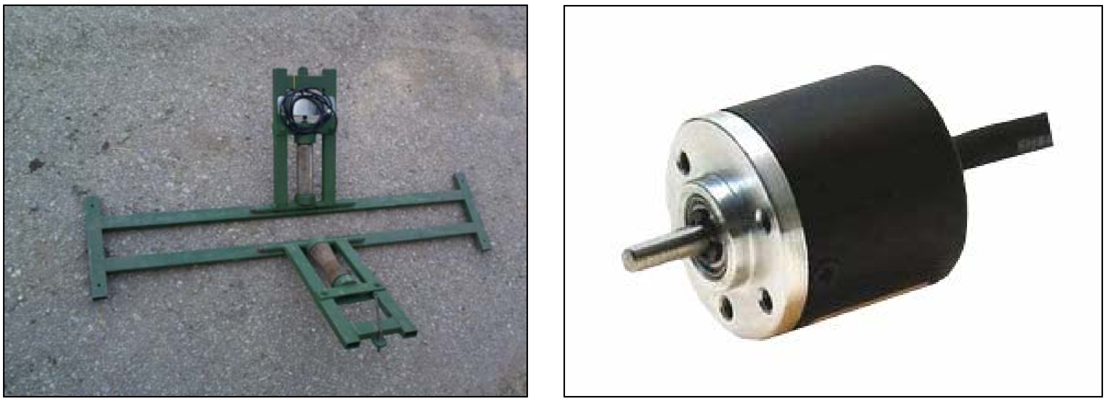

Fig. 3: Frame and MOL 30 sensor

As the basis, we have chosen the connection of the frequency reader with an extended cycle of measuring the number of impulses from the sensor. Values are stored in the operating memory of the microprocessor. These values are then able to be read from the microprocessor and processed by the PC. The device is powered by 12 V DC.

As the main microprocessor, the microcontroller PIC16F877 (Microchip Technology Inc., USA) was used. Its technical details are listed in Table 3. As an auxiliary microprocessor I2C, the microprocessor manufactured by the same American company was used. Its primary task is to count the impulses from the sensor and send the actual value after a request from the main microprocessor. The displaying unit is designed with the use of four 7-segment LED displays, controlled by the main microprocessor. The display has four digits, the two of which represent decimal digits.

Table 3: Technical parameter of microprocessor

Parameter	**Electricity consumption**	**EEPROM memory**	**Power supply**
Value	25 mA	128 KB	2.0–5.5 VDC

The communication unit is used to communicate with the sensor, to transfer the measured values to the connected PC. We are also able to set the number of impulses of the sensor and the perimeter of the cylinder through this communication unit. For communication, the RS232 serial port is used.

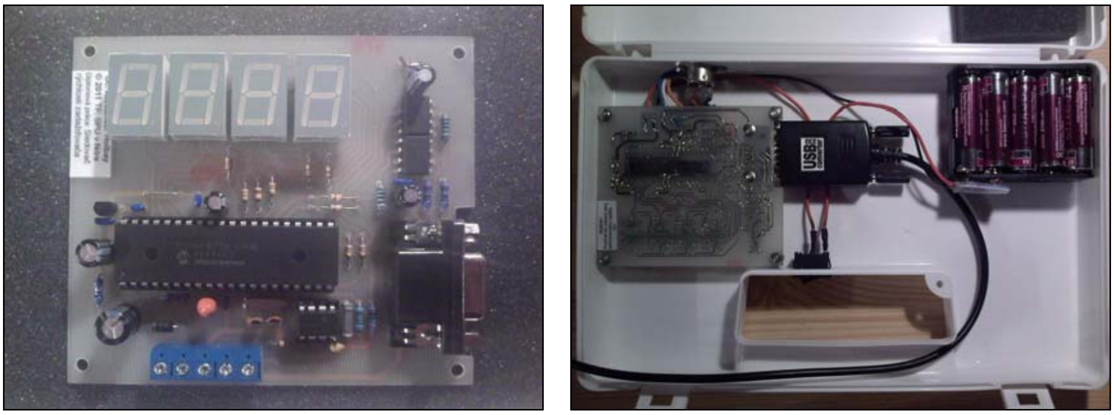

Fig. 4: Completed device

Software

The software was based on the principle of the frequency counter and microprocessor. We used the C programming language.

To write a proper program, we set up a mathematical equation representing the relation between the parameters that influence the speed calculation.

$$v = \frac{n_1 \cdot O_v \cdot 3{,}600}{k \cdot n_2 \cdot 1{,}000}, \text{ m*h}^{-1} \qquad (1)$$

where:

v – hose winding speed, m*h^{-1},

n_1 – number of impulses recorded by the counter in a specified time interval,

O_v – perimeter of the cylinder, mm,

n_2 – number of impulses of the sensor per one cycle,

t – time unit, t=1, s.

The time is an important part of this equation. The time unit was set to 1 because the hose winding speed is measured every second. The next measured value is added to this value, and the sum is divided by 2 to get the average value. The third value is added to this average value, and this procedure is repeated. This calculation is programmed in the microprocessor. In Equation 2, the values of calculations and the time value are combined in terms of optimization.

$$v = \frac{n_1 \cdot O_v \cdot 3.6}{n_2}, \text{ m*h}^{-1} \qquad (2)$$

This program was also written in the C programming language for Windows operating systems. The program represents just a superstructure of terminal communication to ease the user interface. The program has a support for the export of memory into a TXT file. In addition, the program automatically reads the set values right after connection to the monitoring device. The support of COM port is also integrated.

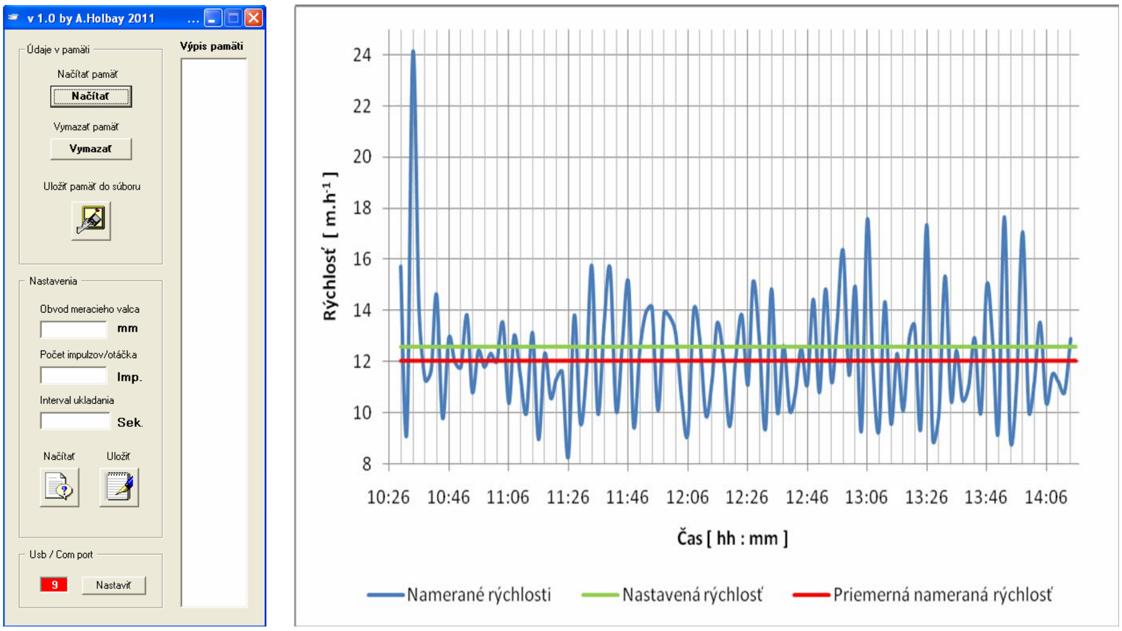

Fig. 5: User interface, results

The measurement was performed on a field of AGROCOOP IMEĽ, a.s. near the Imeľ village. The Bauer Rainstar 90/300 irrigator was equipped with a control electronics BAUER ECOSTAR 4000 S, set to value 12.6 $m*h^{-1}$. The Speedmeter SM2 was placed approximately 150 m from the reel. Weather conditions were suitable for irrigation, clear sky, temperature at the beginning of measurement was more than 30 °C in the shade. Before the measurement, we set the input parameters like the cylinder perimeter (143.8 mm), number of impulses of the sensor (1,024 $impulses*cyc^{-1}$) and the interval of saving operations (120 s). The graph of hose winding speed variability is shown in Fig. 5. In this graph, we marked the average and the set value. The average value of working speed was **Chyba! Nenašiel sa žiaden zdroj odkazov.**12.26 $m*h^{-1}$. The absolute error of measurement was 0.34 $m*h^{-1}$.

Table 4: Descriptive statistics

Parameter	**Amount of spray, m*h^{-1}**
*Average, m*h^{-1}*	12.26
*Standard deviation, m*h^{-1}*	2.41
*Difference max. – min., m*h^{-1}*	15.84
*Minimum, m*h^{-1}*	8.27
*Maximum, m*h^{-1}*	24.11
*Sum, m*h^{-1}*	1,397.17
Count, pcs	114
Reliability (95.0 %)	0.45
Coefficient of variation, %	19.64

Conclusion

The main goal of the designed device is to ease the process of monitoring the hose winding speed of an irrigator. After modernization of this device, there is no need a human to control the device and write down the measured values. On the other side, we provided the monitoring of hose winding speed on a reel. After receiving the data and its evaluation, we can perform operations needed to increase the quality of work of specified irrigation machine. We just download the results into PC and evaluate them. The device is able to store 122 values; it is limited only by the used internal memory of the microprocessor. The export of measured values is performed by connection to RS 232 or USB. The interval of saving the measured values into the internal memory can be set from 1 s to 32,768 s (approximately 9.1 h).

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