

Influence of operational wear of selected nozzles on the unit outflow rate and transverse distribution of the sprayed liquid

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Abstract. The article presents an assessment of the influence of the operational wear of selected types of pressure flat-stream nozzles on the quality of spraying. The results of the unit outflow rate and the CV index of the transverse distribution of the liquid for the field beam equipped with the tested type of nozzles were assumed as the measure of the grades. The tests were carried out for three types of nozzles with various operational wear. The measurements were carried out on automated spraying test stands. The tests of the unit intensity of the liquid outflow consisted in determining the conversion flow rate from the nozzles and comparing it with the nominal intensity. On the other hand, the transverse irregularities of the fall of sprayed liquid included the determination of the spray irregularity index for the nozzles at three different heights of the beam over the sprayed surface. On the basis of the analysis of the test results, it was found that the increase of the outflow rate for individual nozzles caused by their operation has a significant impact on the increase of the CV index of the spraying beam composed of the appropriate number of tested nozzles.

Key words: nozzle, spraying; laboratory stand, outflow rate, unevenness of transverse distribution of liquid, CV index.

INTRODUCTION

Sprayers' nozzles are a basic element that has a significant impact on the correct use of chemicals (quality of spraying). The results of attestation tests of sprayers used in agriculture, carried out at SKO stations, indicate that nozzles are the most common cause of improper functioning of the sprayer. As a result of the flow of a mixture of water and plant protection agent through the nozzle, the nozzle openings are deformed, which is one of the causes of the change in the value of the outflow intensity of the liquid.

The quality of the nozzles' work is assessed on the basis of CV test results, determined for individual nozzles and sprayer assemblies placed on the spraying beam, as well as by measuring the outflow rate simultaneously for the spraying beam nozzles assembly or individually for the removed spray nozzles. Some of the EU countries (Belgium, France, Greece, the United Kingdom) use the measurement of outflow intensity as an assessment of the work quality of the nozzles. In Poland, Portugal and Sweden, the determination of the CV index and outflow rate is used to assess the quality of nozzles [Wehmann, 2012], [Sawa et al. 2002].

Testing the intensity of liquid outflow from spray nozzles removed from the boom frames allows to determine which of the nozzles is worn and is not suitable for further use. This eliminates the influence of pressure on the field boom and damage to the anti-drip valves on the result of the technical examination of the nozzles [Koszel, Hanusz 2008]. Wear may not be detected during the visual inspection of the nozzle. The wear status can be observed using an optical comparator. The edges of the worn nozzle look more rounded than the edges of the new nozzle. The best way to determine if the nozzle is over-used is to compare the outflow rate in the used nozzle and the outflow rate in the new nozzle of the same size and type. However, the quality of the treatment, made with the use of nozzles, can be assessed using the CV index, taking into account the use of nozzles located on the sprayer beam. An important aspect is also the change in the diameter of droplets in their generated spectrum. There is no doubt that the nozzles are one of the most opinion-giving elements of the sprayer affecting the correct use of chemical plant protection products [17]. For this reason, such a great deal of attention is now paid to the design of nozzles, paying attention to construction materials and manufacturing technology, in order to achieve the highest possible resistance to wear and tear. It is also important to verify them during periodic attestation at stations (SKO)

and in basic research conducted by research institutes and scientific centers.

PURPOSE OF THE PAPER

The purpose of the paper is to determine the impact of the operational degree of wear of pressure field nozzles on the quality of spray applied on the basis of a unitary expenditure as well as the lateral distribution of the sprayed liquid.

It was assumed that on the basis of the results of laboratory tests, the relationship between the degree of wear of individual nozzles and the unit liquid expenditure and the transverse irregularity of spraying index will enable the analysis and evaluation of the quality of the spraying process.

MATERIAL AND RESEARCH METHODS

The research was carried out in the laboratory of the Institute of Mechanical Engineering of the Warsaw University of Technology, Branch in Płock. The stand on which the transverse irregularity tests were carried out was equipped with a fully automated multi-grooved table, together with a measurement and control system for controlling the spraying process [3, 4, 5]. The view of the laboratory stand is shown in the figure 1.

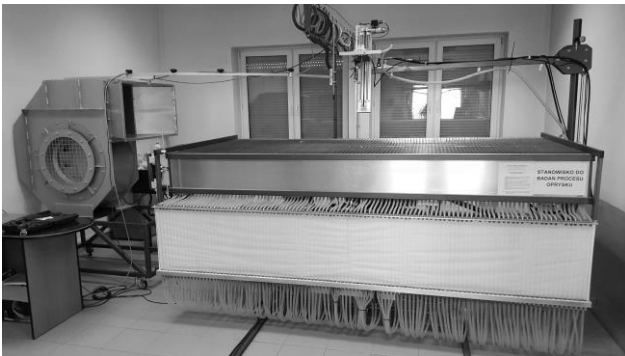


Fig. 1. View of the laboratory stand used in the research

To test the intensity of liquid outflow, a station consisting of a flow meter together with a measurement and control system and developed computer software was used. Figure 2 shows the general view of the stand.

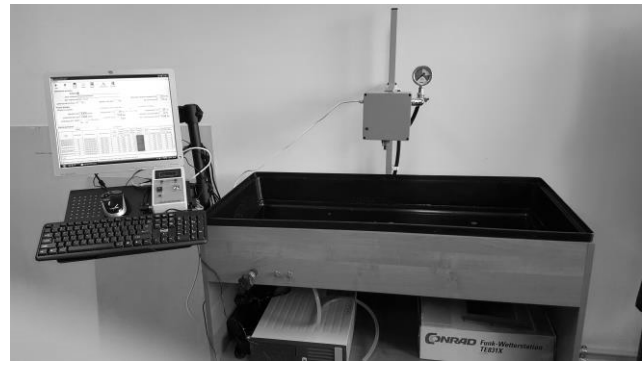


Fig. 2. Measuring stand for testing the outflow rate of liquids

Laboratory tests using the above-mentioned stands were carried out in accordance with the requirements and recommendations of ISO standards [9, 10, 11, 12, 13], and in particular:

- the working medium was pure water free from solid suspensions, and its temperature did not exceed the range from 10°C to 25°C,
- the accuracy of reading the liquid volume in a single measuring vessel was ± 1 ml, which results from the way of measurement (digital image analysis),
- the ambient temperature during the tests was from 15°C to 20°C,
- the accuracy of the working pressure reading was $\pm 0,1$ bar,
- the time of performing a single measurement was longer than 30 seconds,
- the accuracy of reading the nozzle height above the measuring table was $\pm 0,01$ m.

The subject of laboratory tests were 13 nozzles with a different degree of wear, by two well-known and valued companies that are widely used in field sprayer constructions. The nozzles most commonly used in farms with normalized sizes 03 and 04 were considered. Used nozzles were randomly selected from 3 batches of 12 pieces, disassembled from sprayers. To compare the results, the tests also included new nozzles. The following nozzles were used in the tests:

- nozzles by LECHLER with IDK 120-03 symbol (ejector flat-stream nozzles with stream angle of 120°, size 03 and nominal outflow rate of 1,2 l/min), where there were two new and three after a 5-years long use period (about 150 hours),
- nozzles by ALBUZ with AVI ISO 11004 symbol (ejector flat-stream nozzles with stream angle of 110°, size 04 and nominal outflow rate of 1,6 l/min), where three was one new and three after 4-years long use period (about 150 hours),
- nozzles by LECHLER with LU-120-04 symbol (universal flat-stream nozzles with stream angle of 120°, size 04 and nominal outflow rate of 1,6 l/min),

where three was one new and three after 4-years long use period (about 300 hours).

As a criterion for assessing the technical condition of the nozzles, according to European standards, the expenditure tolerance ($\pm 5\%$) of nominal flow was assumed for new nozzles. For used sprayers, the test is evaluated negatively when the value of the outflow rate of the liquid does not fall within the tolerance range ($\pm 10\%$), [8].

As the criterion for the evaluation of the results of the research on the quality of work of the tested nozzles one adopted: the value of CV index (with a maximum limit of 10%), and the number of measuring cylinders in which the liquid volume does not exceed $\pm 10\%$ of their mean value.

During the CV index measurements, a constant height value of the spraying beam over the surface of the measuring table of 0.4, 0.5 and 0.6 m respectively and a working pressure of 3 bar were maintained. The time of each measurement was 120 s. The automatic control system, in which the laboratory stand was equipped, made it possible to eliminate fluctuations in the working pressure and obtain the assumed spray dose on a constant level during measurements. During the measurements, the values of the abovementioned working parameters of the stand and the volume of liquids collected in individual measuring cylinders of the grooved table were recorded in the computer memory. The original computer program, in which the laboratory stand was equipped, made it possible to determine the value of the CV index for both individual nozzles and the so-called "virtual" spraying beam made

up of an appropriate number of tested nozzles. Simulation of the "virtual" beam is based on the volume of liquid collected from 25 mm wide grooves and the assembly of streams from the area of their full coverage, and then aggregation of these volumes to a groove width of 100 mm (in accordance with the requirements of ISO standards). The volume of liquid coming from neighboring nozzles on the "virtual" beam is aggregated in such a way that the liquid streams overlap and the nozzle axes are spaced out every 0.5 m, which gives the same distribution of liquid as for the actual field sprayer beam [15].

During measurements of the outflow rate, successive new and used nozzles subjected to the research were mounted on a station equipped with a flow meter and a measurement and control system supported by a computer program. The measuring stand operates in a closed liquid system, where the factor used in the tests was pure water. The tests were carried out at a liquid pressure of 3 bars. The measurement time for a single nozzles was 60 seconds. The measurement and control system, via a computer program, recorded the flow rate, operating fluid parameters and ambient parameters.

RESEARCH RESULTS AND DISCUSSION

Table 1 presents the results of laboratory measurements conducted.

Table 1. Results of laboratory measurements of flow rate and CV index for nozzles included in the research program

Nozzles								
new								
No.	Nozzle type	Nominal pressure [bar]	Nominal outflow rate [l/min]	Average conversion outflow rate [l/min]	Outflow rate difference [%]	Beam height [mm]	CV nozzle [%]	CV beam [%]
1	LECHLER IDK 120-03	3	1,2	1,18	1,7	400	65,3	6,2
						500	57,4	4,9
						600	54,4	2,1
2	LECHLER IDK 120-03	3	1,2	1,16	3,3	400	65,9	5,2
						500	58,2	4,3
						600	54,2	3,1
used - about 150 hours								
3	LECHLER IDK 120-03	3	1,2	1,31	9,2	400	67,8	7,1
						500	61,4	8
						600	58	7
4	LECHLER IDK 120-03	3	1,2	1,29	7,5	400	64,8	6,2
						500	62,2	7,7
						600	56,1	6,5

5	LECHLER IDK 120-03	3	1,2	1,32	10	400	68	7,3
						500	63	9,9
						600	62	8,1
new								
6	ALBUZ AVI ISO 11004	3	1,6	1,54	3,7	400	49,6	6,2
						500	44,1	5,5
						600	40,9	8,1
used - about 150 hours								
7	ALBUZ AVI ISO 11004	3	1,6	1,63	1,9	400	55,9	4,8
						500	47,8	3,1
						600	50,5	8,5
8	ALBUZ AVI ISO 11004	3	1,6	1,62	1,3	400	54,5	2,8
						500	48	2,2
						600	49,2	8,5
9	ALBUZ AVI ISO 11004	3	1,6	1,76	10	400	57,7	7,5
						500	52,1	9,3
						600	52	13,2
new								
10	LECHLER LU-120-04	3	1,6	1,58	1,25	400	70,4	3,7
						500	63,6	3,2
						600	56,4	3
used – about 300 hours								
11	LECHLER LU-120-04	3	1,6	1,7	6,25	400	68,7	8,1
						500	68	5,7
						600	63,2	4
12	LECHLER LU-120-04	3	1,6	1,73	8,1	400	65,5	8,9
						500	63,8	5,4
						600	65,2	4
13	LECHLER LU-120-04	3	1,6	1,75	9,4	400	70,3	9,7
						500	66,1	6
						600	66,2	4,3

The results were summarized for the nominal pressure and outflow rate assumed in the research. For each nozzle tested, the CV index values for the single nozzle and the "virtual" sprayer beam were presented. The results were ranked by the order of measurements. The determined values of the CV index for individual nozzles have a comparative role, whereas the values determined for the spraying beam become a direct assessment of the quality of spraying. The measurements of the outflow rate for the subsequent examined samples were presented in the form of the average value of the calculated outflow rate and the percentage difference between the nominal and measured outflow rate.

The outflow rate for new nozzles was in the tolerance field ($\pm 5\%$) of the nominal outflow. For LECHLER IDK 120-03 nozzles, with values of 1.7% and 3.3% respectively, for the ALBUZ AVI ISO 11004 nozzle, 3.7%, for the LECHLER LU-120-04 nozzle with a value of 1.25%. The LECHLER LU-120-04 nozzle turned out to be the best one with the smallest difference in relation to the nominal outflow. Analysis of results for LECHLER IDK 120-03 nozzles that have worked for 150 hours indicates an increase in outflow. There were values in the range of $1.29 \div 1.32$ l/min, which do not exceed the permissible value of $\pm 10\%$ of the difference in outflow. There was also a tendency for the CV index to increase for a single nozzle, while the CV index for the beam consisting of the same nozzles increased. It was also observed that for the used LECHLER IDK 120-03 nozzles, none of the CV values for the beam exceed 10%. The selected liquid distributions for nozzles No. 4 and 5 are shown in Figures 3 and 4.

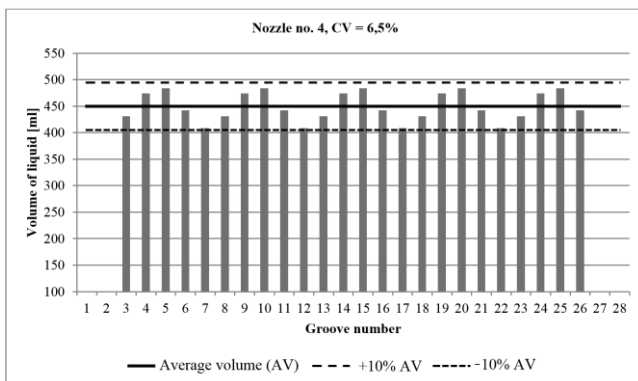


Fig. 3. Distribution of sprayed liquid for used LECHLER IDK 120-03 nozzle located on a virtual beam at 600 mm height and groove width of table of 100mm.

Source: own elaboration

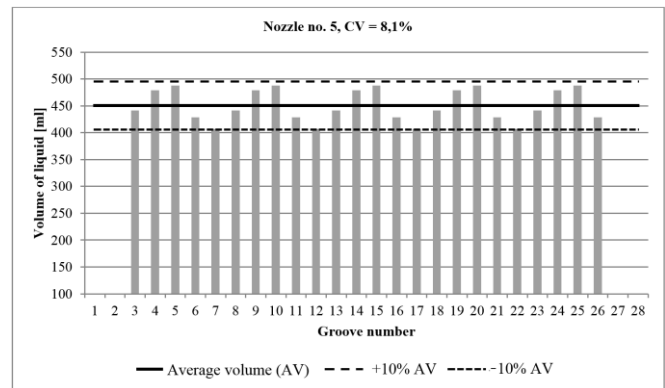


Fig. 4. Distribution of sprayed liquid for used LECHLER IDK 120-03 nozzle located on a virtual beam at 600 mm height and groove width of table of 100mm.

Source: own elaboration

It was noticed that for the value of the CV index of 6.5% (nozzle 4), the number of cylinders with a deviation exceeding $\pm 10\%$ is 0, whereas with a CV increase to 8.1%, (nozzle 5), the number of cylinders with exceeded deviation is 4.

Analysis of the results for ALBUZ AVI ISO 11004 nozzles that have worked for 150 hours also indicates an increase in outflow. There were values in the range $1.62 \div 1.76$ l/min, which do not exceed the permissible value of $\pm 10\%$ of the difference in outflow rate. The result at the level of + 10%, was noted for the nozzle No. 9. A tendency of the CV index' increase for a single nozzle was observed, while the CV index for the beam consisting of the same nozzles increased simultaneously. It has been noted that for nozzle No. 9 (ALBUZ AVI ISO 11004), the value of the CV index for the beam set at 600 mm is 13.2% and exceeds 10% of the limit value.

For LECHLER LU-120-04 nozzles which worked for over 300 hours, there was a significant difference in the outflow rate between the result for the new nozzle and the used nozzles. A significant increase in the outflow rate was noted for all nozzles where the difference in outflow rate was in the range of $6.25 \div 9.4\%$. The results obtained indicate their significant consumption. The results of the CV index for the beam do not exceed the permissible value of 10% for all the heights of the beam setting over the surface to be sprayed. The same tendency of the CV index' increase for all examined nozzles was observed. It can be concluded that LECHLER LU-120-04 nozzles have very good wear resistance despite 300 hours of work.

CONCLUSIONS

Based on the analysis of the obtained results, it was concluded that:

- an important factor in assessing the degree of wear of the nozzles may be the result of the CV index test, determined for the nozzles assemblies placed on the spraying beam, as well as the measurement of the outflow rate for the individually removed nozzles,
- all used nozzles included in the tests, have achieved the value of the average conversion outflow rate within the permissible level, $\pm 10\%$ of the outflow rate difference,
- all nozzles covered by the tests, except for ALBUZ AVI ISO 11004 (No. 9, CV = 13.2%, for the height of the setting of 600 mm), have obtained the results of a CV index for the beam within the admissible range of 10%,
- increase in the outflow rate for individual nozzles caused by their operation, has a significant impact on the increase in the CV index value of the spraying beam composed of the appropriate number of tested nozzles.

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