Influence of fan flat nozzles wear degree on drop tracks size

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Abstract: The subject of the analysis was the influence of working parameters (working pressure and working speed) on the drop tracks size and changes in the flow rate level from flat fan nozzles. New nozzles were tested. It was found that the increase in the flow rate depends on the nozzles size and their working time, and that the increase in the drop track size is caused by the nozzles wear. An excessively low working pressure or working speed causes drops merging. This phenomenon is especially dangerous when using nozzles with a considerable degree of wear for agricultural spray since it poses ecological threat to the environment.

Keywords: spray; drop tracks size; nozzles wear; flow rate

In view of the rising requirements to reduce environmental pollution, it is important to use plant protection agents with due precision.

The quality of spraying machine work is affected by several technological, technical, and climatic factors, the most important of which include the type of machine, choice of nozzles, appropriate spray parameters, temperature, and humidity, as well as adherence to the instructions of the plant protection agents producers (Sawa *et al*. 2003).

It should be noted that the nozzle wear degree has a decisive effect on the spray quality. The speed of the nozzle wear depends on the nozzle outlet size, material, and working time (Wargocki 1995). Womac (2000) evaluated nozzles by measuring the drop spectrum size and distribution coefficient of the sprayed liquid fall. On the basis of his research, the author states that the nozzle wear degree is affected by the precision of its production in the factory. In his studies, Wargocki (1995) concentrates on the relation between the nozzle orifice wear and the material the nozzle is made of. The author also reports that there is a clear correlation between the orifice size and nozzle wear – in nozzles with smaller orifices an increase in liquid flow rate is higher. Similar conclusions were also drawn from the studies conducted in the USA. Testing flat fan nozzles made of different materials (brass, plastic, stainless steel) and of different sizes, Reichard *et al*. (1991) also found that the smaller the nozzle orifice, the shorter the time of the nozzle wear.

Agricultural sprays consist in an even covering of agrofags with drops of the required diameter. A good effect of chemical plant protection depends on several factors. The most important ones include: preparation dose, appropriate time of application, atmospheric conditions, and especially sprayer technical parameters (type of nozzles used, working pressure, working speed). The appropriate drop size affects the spray quality. The quality of performing the plant protection spray is usually determined by the measurements of:

– number of drops per 1 cm^2 of a leaf (drops No. per cm^2)
– drop coverage degree of the surface (%)

In addition, Gajtkowski (2000b) also includes the preparation mass per 1 cm^2 of a leaf ($\mu g/cm^2$) among the factors mentioned above. Moreover, the degree of the drop drift in the spray area or drops flowing off the protected surface must be considered as important.

Achieving a good quality of spray requires using technically efficient plant protection equipment, especially nozzles which do not show excessive wear degree. The degree of the nozzle wear is determined on the basis of an increase of the nozzle flow rate in relation to the nominal flow rate in percentages. Since during the nozzle work the flow of the plant protection liquid (water + chemical agent), i.e. mechanical destruction, causes an increase in the nozzle outlet orifices, the liquid flow rate also rises (Reichard *et al.* 1991). A decisive role in the degree of the nozzle working wear is played by physical and chemical properties of water (viscosity, density, surface tension, and hardness) as well as by the form of the plant protection agent (substance, powder, suspension). It is generally accepted to replace nozzles when the liquid flow rate has increased by 10% in relation to the catalogue data. The consequence of the nozzle wear is an increase in drops mean diameter. The nozzle wear influences the merging degree of drops, which causes drops to flow off the surface of the protected plants. Consequently, the plant protection agents permeate into the underground water and contaminate the environment (Biziuk *et al.* 2001). If nozzles generate very small drops, these are drifted away by wind or the liquid evaporates before their falling on the protected plants.

MATERIAL AND METHODS

Laboratory nozzle wear tests were conducted in the Department of Agricultural Equipment Exploitation and Management in Agricultural Engineering, University of Life Sciences in Lublin.

The aim of the study was to determine the influence of the changes of the agricultural nozzles technical condition on the drop tracks size.

New nozzles (LECHLER 110-03 (plastic)) of nominal flow rate 1.17 l/min were destroyed by 3 bar pressure. A testing stand with sprayer boom travel speed of 5 km/h (1.39 m/s), 7 km/h (1.94 m/s), and 9 km/h (2.50 m/s) was used for the drop placement on a model surface. The model surface consisted of a film strip of the size 100 × 10 cm. The working liquid for spraying of drops was 2% water solution of nigrosine.

For spraying drops onto the model surface, a testing stand was used (Figure 1) equipped with a mobile trolley with a mounted sprayer boom. The trolley was powered by an electric engine with transmission in order to reach different speeds.

The measurements were recorded at the pressure of 1 bar (0.1 MPa), 3 bars (0.3 MPa), and 5 bars (0.5 MPa). The tests were performed with 5 repetitions.

The nozzles were destroyed to reach 2%, 4%, 6%, 8%, and 10% wear rates and to reach 5% and 10% wear rates, which was calculated by comparing the changes in the liquid flow rate from each nozzle to the nominal flow rate.

The measurements of the liquid flow rate from the nozzles dismounted from the boom spraying tips were performed using an electronic device (Figure 2). The device was equipped with an elec-

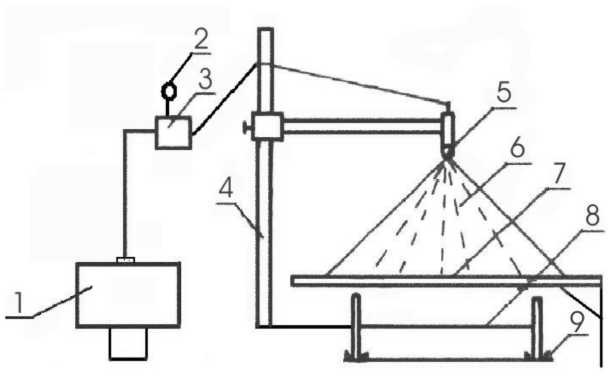

Figure 1. Diagram of device for spraying drops onto model surface
1 – Manual sprayer, 2 – Manometer, 3 – Control valve, 4 – Arm with a section of sprayer boom, 5 – Nozzle, 6 – Stream of sprayed liquid, 7 – Stationary table, 8 – Trolley, 9 – Guide

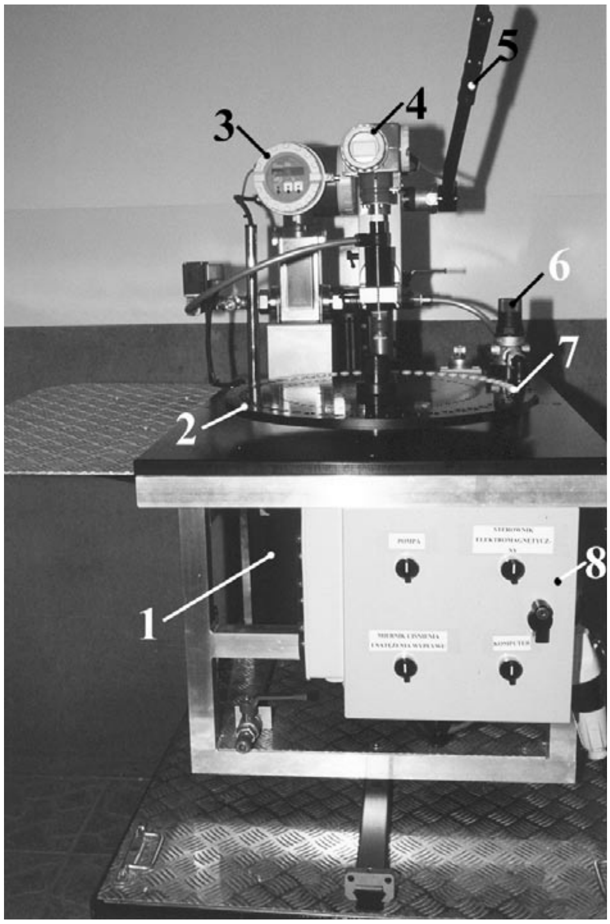

Figure 2. Device for measuring liquid flow rate from nozzles dismounted from the boom spraying tips
1 – Water tank, 2 – Rotational table, 3 – Flow rate measuring electromagnetic instrument, 4 – Pressure measuring electronic instrument, 5 – Control lever, 6 – Pressure control, 7 – Nozzles, 8 – Control box

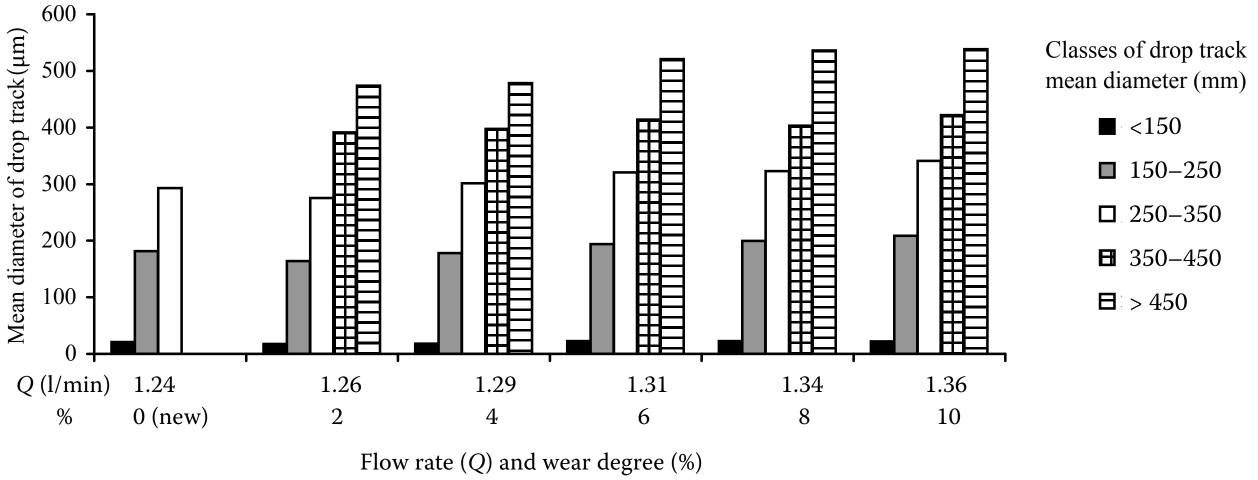

Figure 3. Changes of drop track size as a function of flow rate changes, respectively for new nozzles and nozzle of 2, 4, 6, 8 and 10% wear nozzles LECHLER 110-03 (plastic)

tromagnetic instrument measuring the liquid flow rate (made by Endress + Hauser Company) and a pressure measuring electronic instrument (made by Endress + Hauser Company).

Water solution of kaolin was used for destroying the nozzles. 9.8 kg of kaolin were added into 150 l of water (Ozkan *et al.* 1992a).

Since there is no uniform classification of the drop sizes (e.g. the classification used in England, western European classification, the classification used in the USA), the following five ranges of the drop size were assumed:
- < 150 µm,
- 150 ÷ 250 µm,
- 250 ÷ 350 µm,
- 350 ÷ 450 µm,
- > 450 µm.

After drying up of the drops on the model surface, 5 images of the size 5 × 5 cm were scanned from each film strip. The first image was scanned in the nozzle symmetry axis, and then 10 and 20 cm to the left and right from the axis. The drop track diameter, spray coverage degree, and number of drops were calculated using the computer programme Image Pro+ made by Media Cybernetics. The comparison of means was conducted with the Tukey's least significant difference (LSD) test, at a significance level $P = 0.05$. The results are expressed as the mean standard deviations.

RESULTS AND DISCUSSION

Figure 3 shows the changes in the mean diameter of the drop track on the model surface as a function of changes in the flow rate from plastic nozzles.

Y-axis shows that the flow rate values correspond to the flow rate through new nozzles as well as worn nozzles with 2%, 4%, 6%, 8%, and 10% of the wear degree. Analysing the test results (Figure 3), it was found that the nozzles with the nominal flow rate produce drop tracks which can be qualified as small drop spray and medium drop spray. An increase in the flow rate changes the classifications of the spray drop track. After achieving 10% of the nozzle wear degree, the nozzles produce drop tracks which can be qualified as large drop spray. The increase in the flow rate and drop spectra makes the plant protection agents drip off plant surfaces, which causes the pesticide to permeate into soil and underground water. An excessive number of drops on the plant surface also causes drop merging, which deteriorates the spray quality and brings about economic losses.

The size of drops produced by a nozzle is connected with the nozzle type, liquid flow rate, and working pressure. Nozzles with a high wear degree not only dose drops with larger diameters but also use a larger volume of liquid. In such a situation, it is necessary to regulate the sprayer working parameters, which in the conditions of agricultural practice means reducing the pressure rather than increasing the working speed. Such a procedure bears consequences for both the quality and economic effectiveness of the spraying as well. If a sprayer is considered with a 12-metre boom and 24 nozzles, each one dosing 1.5 l of liquid per 1 min, then a 20% increase in the liquid flow rate from the nozzles (as a result of their working wear) means wasting the possibility of performing one extra spraying after every 6 consecutive agricultural sprays (Sawa *et al.* 2003).

Figure 4. Change in coverage degree as a function of changes in working pressure (respectively for new nozzles and 5% and 10% wear rates): nozzle LECHLER 110-03 (plastic)

Ozkan *et al.* (1992b) and Zhu *et al.* (1995) investigated drop size spectra of new and destroyed flat fan nozzles produced in different sizes and from different materials. The authors report that drop spectra of new nozzles, though made of different materials, are approximately the same. They also confirm that the nozzle wear rate affects the size of the generated drops. Moreover, the drop sizes increased linearly with the increase of the nozzle size, regardless of the material it was made of.

Measuring the drop sizes is incredibly labour-consuming. At present, a drop spectrum analyser or the computer programme Image Pro+ is used for this purpose. However, the problem of counting the number of two merged drops by the programme still remains unresolved.

Laboratory investigations of the nozzle wear show an increase in the mean diameter of the drop tracks coinciding with the increase in the flow rate. This is the result of the nozzle slit expanding.

Figure 4 shows graphic interpretation of the results concerning the coverage degree as a function of changes in the working pressure and working speed.

Table 1. Mean values of working pressure, nozzle wear degree and working speed with standard deviations in parentheses for coverage degrees and number of drops

	Coverage degrees (%)*	Number of drops (drops/cm^2)**
Working pressure (bar)		
1	49.59 (2.17)	28.27 (1.61)
3	51.76 (4.06)	29.87 (2.86)
5	53.65 (1.89)	31.12 (1.25)
Nozzle wear degree (%)		
0 (new)	47.73 (3.42)	31.05 (1.40)
5	51.15 (8.40)	29.65 (2.48)
10	56.13 (4.98)	28.57 (1.08)
Working speed (km/h)		
5	53.55 (1.68)	28.51 (1.35)
7	51.87 (3.98)	29.86 (2.38)
9	49.58 (2.30)	30.89 (1.03)

*Tukey's least signifiant diference test (α = 0.05) = 0.72

**Tukey's least signifiant diference test (α = 0.05) = 0.35

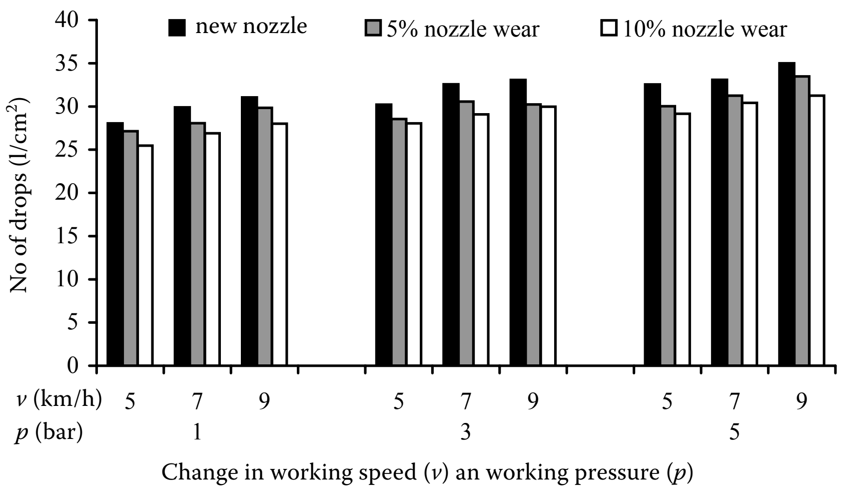

Figure 5. Change in the number of drops per 1 cm^2 as a function of changes in working pressure (respectively for a new nozzle and 5% and 10% wear rates): nozzle LECHLER 110-03 (plastic)

The rise in the working pressure increases the coverage degree. The explanation of this fact is that a high pressure makes the nozzles produce small drops in spite of their wear. As a result, worn-out nozzles dose large volumes of liquid and, consequently, the coverage degree also increases. An increase in the working speed was found to coincide with a decrease in the coverage degree.

An increase was observed in the coverage degree from 49.59% at 1 bar pressure to 53.65% at 5-bar-pressure. The nozzle wear degree also affects the coverage degree, which ranged from 47.73% for a new nozzle to 56.13% for a nozzle with 10% wear degree. Then, an increase in the working speed causes a decrease in the coverage degree from 53.55% at the speed of 5 km/h to 49.58% at the speed of 9 km/h.

Statistical analysis (Table 1) demonstrated that the increase in the coverage degree of the sprayed surface is mainly affected by the working pressure, nozzle wear degree, and working speed.

Similar results of the degree coverage were obtained by Gajtkowski (2000a). Examining new nozzles, made of plastic, at the working pressure of 3 bars and the speed of 7 km/h he obtained the coverage degree of 40%. The coverage degree was also studied by Wachowiak and Kierzek (2000). With TeeJet XR 110-03 nozzles they achieved the coverage degree of 42%.

Excessively low pressure or slow working speed cause the merging of drops. This process is especially dangerous while performing the plant protection spray with nozzles with a high wear rate. Figure 5 shows graphic interpretation of the results concerning the number of drops per 1 cm^2 as a function of changes in the working pressure and working speed.

The number of drops increased from an average of 28.27 drops/cm^2 at 1 bar pressure to 31.12 drops/cm^2 at 5-bar-pressure. With new nozzles, the number of drops was 31.05 drops/cm^2, and with nozzles with 10% wear degree it decreased to 28.57 drops/cm^2. However, for the working speed of 5 km/h the number of drops was on average 28.51 drops/cm^2, and at the speed of 9 km/h it rose to 30.89 drops/cm^2.

The parameter of the number of drops per 1 cm^2 was also investigated by Gajtkowski (2000a). Testing new nozzles made of plastic at the pressure of 3 bars and the speed of 7 km/h, he achieved the number of drops of 35 drops/cm^2.

Statistical analysis (Table 1) demonstrated that the number of the drops generated is affected by the working pressure, nozzle wear degree, and working speed.

CONCLUSION

The investigation confirmed the influence of the nozzle wear on the spray ecological characteristics. An increase in the nozzle wear degree causes changes in the track size left on the sprayed surface. In this case, it must be taken into consideration that a large-drop spray has a limited effectiveness, for example in relation to fungi diseases, and at the same time the drops flow off the protected plants onto the ground surface. An increase in the nozzle wear causes also a rise in the coverage degree. This relation results from generating drops by worn nozzles which leave tracks with larger diameters. An increase in the working speed causes a decrease in the coverage degree. These results can be used in practice because the conducted experiment explained that the nozzle wear degree affects the ecological characteristics of agricultural sprays.

The number of drop tracks decreases with the rise in the nozzle wear rate, which is the consequence of drops merging. A high working pressure in nozzles with a low flow rate as well as using worn-out nozzles presents a considerable ecological threat as these cause, respectively, an increase in the number of drops of smaller diameter (possibility of spray drops drifting) or drops merging and flowing off the plants surface.

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Abstrakt

Milan Koszel (2009): **Vliv stupně opotřebení štěrbinových trysek na velikost kapičkového spektra.** Res. Agr. Eng., **55:** 39–44.

Předmětem analýzy byl vliv provozních parametrů (pracovní tlak a pracovní rychlost) na velikost kapičkového spektra a změnu průtoku kapaliny u štěrbinových trysek. Byly testovány nové trysky. Ukázalo se, že zvýšení průtoku kapaliny závisí na velikosti trysek a na době jejich provozu, a že zvýšení velikosti kapičkového spektra je způsobeno opotřebením trysek. Výrazně nižší pracovní tlak nebo pracovní rychlost způsobuje slučování kapek. Tento jev je obzvlášť nebezpečný, pokud jsou pro postřik používány trysky se značnou mírou opotřebení, což představuje vážnou ekologickou hrozbu pro životní prostředí.

Klíčová slova: postřik; velikost kapičkového spektra; opotřebení trysky; průtok

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