Influence of nozzle wear on flow rate and stream droplets size

V. Duvnjak, D. Banaj, R. Zimmer and V. Guberac

Einfluß des Düsenverschleißes auf die Durchflußmenge und Tropfengröße im Spritzstrahl

1. Intoduction

Adequate and precise pesticide application is necessary due to permanent costs increase of chemical plant protection and requirement for environment pollution decrease, especially of ground water pollution. Large amount of pesticide is dissolved in water prior to their application and used by spraying machines via hydraulic nozzles. Thus they are very important at chemical preparations application in plant protection. Nozzles play an important role at pesticides application: they leak given liquid proportion in a time unit, atomize liquid forming droplets of suitable sizes as well as stream of adequate shape. Changes in the given nozzle functions may affect efficiency of applied chemical preparations.

Field testing of tractor sprayers carried out in the Republic of Croatia showed that more than 1/2 of the tested sprayers worked with overdosed chemical agent per area unit. The main reason for that matter of fact was worn nozzles. Hydraulic nozzles intended for pesticide dispersion and application are made of various kind of materials including brass, plastic, ceramics, stainless steel. Nozzles made of different materials have different wear properties. Other factors affecting orifice wear are as follows: orifice shape and size, spraying pressure, usage time and formule of applied chemical preparation.

Considerable interest in this topic can be seen from the literature and many papers regarding testing of wear of different types of hydraulic nozzles at various working conditions have been published (COMBELLAK and MATTHEWS, 1981;

Zusammenfassung

Diese Arbeit analysiert, wie der Verschleiß von Düsenöffnungen durch einen gefächerten flachen Spritzstrahl die Durchflußmenge, das Tropfenspektrum im Spritzstrahl und die Gleichmäßigkeit der Verteilung des Pflanzenschutzmittels sowie die Spritzbreite beeinflußt. Untersucht wurden aus verschiedenen Materialien hergestellte Düsen. Materialabhängig gab es bedeutende Unterschiede bezüglich relativem Verschleiß der Düsen und deren Verwendungsdauer. Der Test zeigte, daß die aus gehärtetem, rostfreiem Stahl erzeugten Düsen am widerstandsfähigsten gegen den Verschleiß waren. Es folgten die aus rostfreiem Stahl hergestellten Düsen, dann Kunststoffdüsen und am Ende standen Düsen aus Messing. Die Düsen mit geringerer Durchflußmenge wurden eher verschlissen als solche mit größerer Durchflußmenge. Im Vergleich zwischen typenidenten neuen und gebrauchten Düsen zeigte sich, daß bei letzteren der Durchfluß im Spritzstrahlzentrum größer war.

Schlagworte: Düse, Düsenverschleiß, Spritzstrahl, Form des Spritzstrahls, Tropfengröße, Druck.

Summary

Influence of wear of nozzle supplying fan flat stream on flow rate, droplets spectrum in a stream as well as distribution eaveness of control agents was investigated in this paper. Nozzles made of various kinds of materials were taken for the investigation. Relative wear of nozzle orifice of different materials varied considerably with the nozzles usage time. At the end of the test it was determined that nozzles made of hardened stainless steel were according to resistance degree the most resistant to wear followed by stainless steel nozzles, plastic nozzles and nozzles made of brass. Nozzles with lower flow capacity wear more in relation to nozzles with higher flow capacity. The worn out nozzles had considerably higher liquid flow capacity in the stream center regarding the new nozzle of the same type.

Key words: nozzle, nozzle wear, stream shape, droplets size, pressure.

OZKAN et al. 1992; REICHARD et al. 1991). Influence of orifice wear on distribution eveness of control agents is not known sufficiently. Also orifice wear may affect droplets size which is very important factor in achieving satisfying chemical agent efficiency.

The adequate aim of these investigations was to determine influence of nozzle orifice wear on flow rate increase, droplet size and stream shape whereby on distribution eveness of control agent.

2. Methods

Nozzles with fan flat stream and stream angle of 80° were used for the investigations. The investigated nozzles were with nominal flow rates (capacities) of 0.75, 1.6, 2.2 and 3.0 l/min at pressure of 275 kPa. The nozzles were made of brass, stainless steel, hardened stainless steel (Spraying systems Co.), and plastic (Lurmark). Three new nozzles were taken from each type by a random sample method. Investigations of droplets size measuring of new nozzles were carried out prior to nozzles wear test. Droplets size and liquid distribution evenness were measured during the orifice wear test at definite time intervals. Median volume diameter $d_{v0.5}$ was the most important representative diameter and it was taken for analysis of droplets spectrum. It was done so that median volume diameter was calculated at every 2 cm of the stream width, always at the same stream hight viewed from the nozzle orifice due to procedure accuracy (OZKAN and ACKERMANN, 1992).

2.1 Droplets size measuring

Droplets size in a stream obtained from the new and worn nozzles was measured by a lasser instrument „Phase Doppler Particle Analyser“ of „Dantec“ firm. The mentioned device measures size, speed as well as concentration of round liquid and gases particles at the same time.

The investigated nozzle was fixed to the transporter at the distance of 50 cm above lasser ray (of the measuring place). Droplets size was measured at every 2.0 cm of stream width ranging from -40 cm to 40 cm from the stream center (0 cm). Such range includes measuring of droplets size along the whole stream width plus approximately 2.0 cm from both stream sizes. Spraying pressure's value was 275 kPa in all experiments.

2.2 Orifice wear test

After droplets size measuring of new nozzles had been done they were subjected to orifice wear test. These researches were carried out at the testing station consisting of the main liquid tank of 200 l capacity with closed (circular) liquid flow. Water added by 0.1 % of Agral 90 was used for the investigation. Agral 90 is a non-ione wetter in the liquid state (condenser containing 900 g/l of nonil phenol polyetoxilate) which is mostly added to pesticides in order to change wettering properties of pesticides droplets. Nozzles made of different materials but of the same nominal capacity were investigated at the same time.

3. Results and discussion

3.1 Influence of nozzle wear on flow rate

Measurings by which flow rate increase was determined due to orifice wear were stopped when flow increase occured by about 10 % with nozzle made of stainless steel. Measuring of wear of nozzles made of brass were stopped earlier in relation to nozzles made of other materials since brass nozzles wore out significantly faster.

Table 1: Percentage of flow rate increase of worn nozzles (nozzle wear time expressed in hours is in brackets)

Tabelle 1: Erhöhung der Durchflußmenge bei gebrauchten Düsen (in %); (in Klammern: die Zeit des Düsengebrauchs in Stunden)

Nozzle material	Percentage of flow rate increase of worn nozzles			
Brass	21,5 (25)	18,3 (48)	19,7 (108)	19,0 (265)
Plastic	16,6 (48)	11,1 (96)	12,8 (240)	12,4 (348)
Stainless steel	12,7 (48)	10,9 (96)	11,4 (240)	10,2 (348)
Hardened stainless steel	1,2 (48)	4,6 (96)	4,4 (240)	4,8 (348)
Nominal flow rate (l/min)	0,75	1,6	2,2	3,0

Table 1 presents nozzle type according to material, number of hours the nozzle was subjected onto wear test and percentage of flow rate has increased at the end of the test. Values of flow rate percent increase are of mean values for the three nozzles of the same capacity, made of the same material, tested in each nozzle group.

Figure 1 presents flow rate changes with the usage time relative to nominal flow rates of 0.75, 1.6, 2.2 and 3.0 l/min. Each point on the curve presents average value for

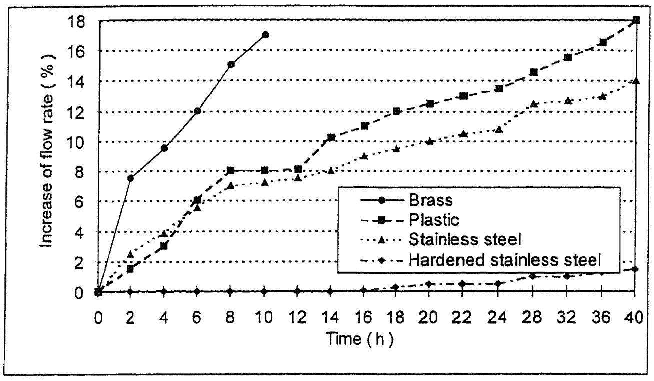

Figure 1: Influence of kind of materials on nozzle wear at nominal flow rate of 0.75 l/min
Abbildung 1: Einfluß des Materials auf den Düsenverschleiß bei einer nominalen Durchflußmenge von 0.75 l/min

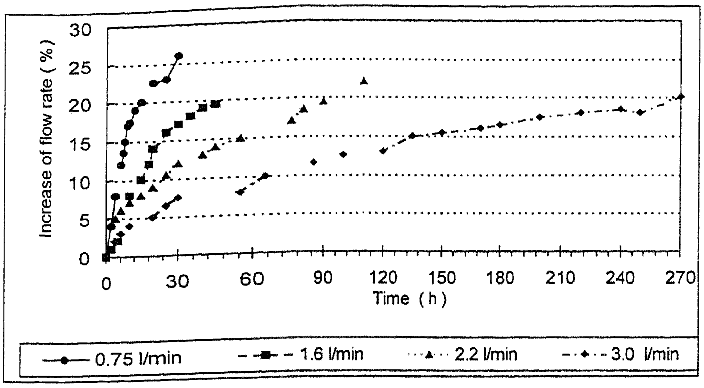

Figure 2: Influence of flow rate on brass nozzless wear
Abbildung 2: Einfluß der Durchflußmenge auf den Verschleiß von Messingdüsen

three same nozzles (per material and flow rate). Flow rates of brass nozzles increased considerably faster in the same period in relation to all other materials at all nominal capacities. Also, flow rate amount with nozzles made of hardened stainless steel wore considerably slower in relation to all other materials at the same testing time with all nominal capacities. Curves of flow rate increase for plastic nozzles were always, regarding the same time of use, between curves of nozzles made of brass and those made of stainless steel.

Nozzles made of stainless steel had averagely 5.4 times longer time of use than those made of brass before their flow rates increased 10 % in relation to nominal capacity for all investigated nominal capacities. The comparison of nozzles made of stainless steel and plastic showed that those made of stainless steel had longer usage time than with nominal capacities of 0.75 and 3.0 l/min. However, plastic nozzles had longer usage time with nominal capacities of 1.6 and 2.2 l/min before their flow rates increased 10 % in relation to nominal capacity.

Figure 2 shows influence of usage time and nominal capacity of the nozzle on flow rates increase for nozzles made of brass. Similar results were also obtained with nozzles made of plastic, stainless steel and hardened stainless steel. The investigations showed that brass nozzles, especially at lower nominal capacities wore very fast. Figure 2 shows 20 % increase of flow rates after only 15 hours of nozzle use for nominal capacity of 0.75 l/min. Nozzles with higher nominal capacity had longer usage time before their nominal capacity increased by 10 %.

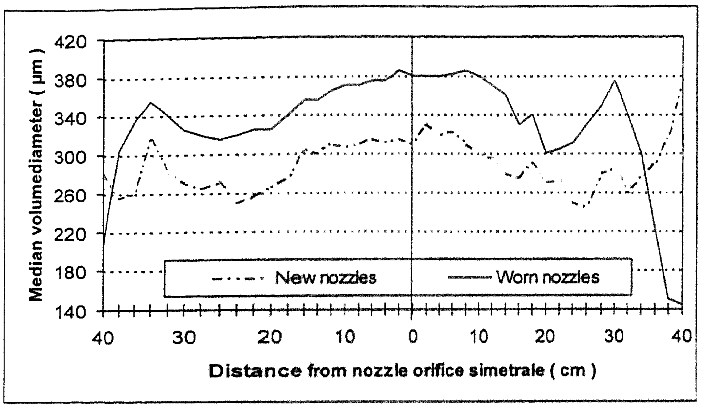

Figure 3: Median volume diameter of new and worn brass nozzles with nominal flow rate of 3.0 l/min
Abbildung 3: Durchschnittlicher Volumendurchmesser der neuen und gebrauchten Messingdüsen bei einer nominalen Durchflußmenge von 3.0 l/min

3.2 Influence of nozzle wear on droplet size

Figure 3 shows values of median volume diameter ($d_{v0.5}$) per stream width for new and worn nozzles made of brass of nominal capacity of 3.0 l/min. Apart from the materials they are made of, values of median volume diameter at nominal capacity of 0.75 l/min were generally lower in the stream center with both new and worn nozzles. Values of median volume diameter of all other new and worn nozzles with nominal capacities of 1.6, 2.2 and 3.0 l/min reduced starting from the stream center and began to increase at about ± 20 cm from the stream center by 3.0 l/min of brass nozzle, as it is presented in Figure 3. Values of median volume diameter at new nozzles with the same nominal capacity but made of different materials were approximately equal.

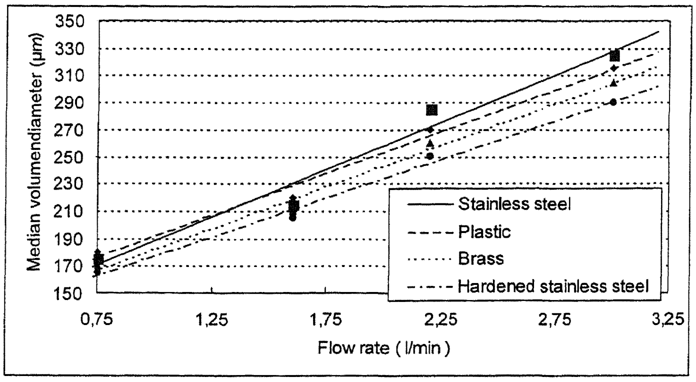

Figure 4: Influence of flow rate on median volume diameter at new nozzles made of various materials

Abbildung 4: Einfluß der Durchflußmenge auf den durchschnittlichen Volumendurchmesser bei neuen Düsen aus verschiedenen Materialien

Figure 4 shows values of median volume diameter increase linearly with nozzle capacity increase, regardless of nozzle material. Similar, median volume diameter of the new and worn nozzles made of brass and stainless steel was linearly increasing with capacity increase of the investigated nozzles. Thus values $d_{v0.5}$ were higher at worn nozzles than at the same (according to nominal capacity and material) new ones. The highest percentage of flow rate increase of 30 % was measured with nozzles made of brass with nominal capacity of 2.2 l/min.

4. Conclusion

Relative nozzle orifice wear caused by different materials may vary considerably with usage time. Nozzles made of stainless steel had averagely 5.4 times longer usage time than those made of brass before their flow rates increased by 10 % in relation to nominal capacity. It appeared to be with all investigated nominal capacities. Flow rates of brass noz'les increased most, whereas flow rates of nozzles made of hardened stainless steel increased lowest with the same usage time for all investigated materials and nominal capacities. Flow rate of plastic nozzles decreased slightly for the short initial usage time before it started increasing above nominal capacity. Some plastic nozzles had longer usage time than those made of stainless steel at the point of 10 % flow rate increase. Percent flow rate increase varied with approximately usage time square root. Values of median volume diameter $d_{v0.5}$ at nominal capacity of 0.75 l/min were generally lower in the stream center with both new and worn nozzles, regardless nozzle material. Values $d_{v0.5}$ of all new and worn nozzles at other nominal capacities (1.6, 2.2 and 3.0 l/min) decreased at the beginning starting from the stream center. Then $d_{v0.5}$ values started increasing at about ±20 cm from the stream center keeping this trend to stream edges. Values $d_{v0.5}$ at new nozzles with the same nominal capacity but of different material were approximately equal. Also, values $d_{v0.5}$ of the new nozzles increased linearly with nozzle capacity increase regardless nozzle material. Similar, values $d_{v0.5}$ of worn nozzles made of brass and stainless steel increased linearly with nozzle capacity increase.

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