AGRONOMSKI GLASNIK 4/2009.
ISSN 0002-1954

Original scientific paper
Izvorni znanstveni članak

EFFECT OF ORIFICE WEAR OF BOOM SPRAYER NOZZLES ON SPRAY CHARACTERISTIC

UTJECAJ TROŠENJA OTVORA MLAZNICA RATARSKIH PRSKALICA NA KARAKTERISTIKE MLAZA

ABSTRACT

Objectives of this investigations were to determine effects of nozzle wear on some most important spray characteristic. In detail, flow rates, spraying angle and distribution pattern were checked and compared with data taken from firms informations. The investigated nozzles were flat fan type, made from different materials. Flat fan nozzles are the most common used tip of nozzles in applying pesticides in Croatian arable farming. The relative wear rates of nozzle materials varied greatly with differnt time of use. At the end of test periods, hardened stainless was the most resistant to wear, followed, by stainless steel, plastic and brass nozzles.

Nozzles with lower flow rates wore at faster rates compared to nozzles with higher flow rates. Analyzing the spray angles it was determined that an increase in flow rate due to nozzle wear corresponded to a reduction in the spray angle. There was little difference between the spray deposit distributions of new and worn fan nozzles in widths of patterns. However, the worn nozzles delivered greater volumes of liquid in the centers of patterns.

Key words: nozzle, wear, nozzle material, flat fan type, spray, spraying angle, spray pattern

SAŽETAK

Cilj istraživanja bio je utvrditi utjecaj trošenja otvora mlaznica ratarskih prskalica na neke najznačajnije karakteristike mlaza. Ispitivani su i mjereni protoka tekućine (l/min), kut mlaza, te raspodjela tekućine po površini, kao najznačajniji kvalitativni parametri mlaza. Isti imaju presudan utjecaj na preciznost i učinkovitost pri kemijskoj aplikaciji pesticida. U ispitivanje su uzete mlaznice s lepezastim spljoštenim mlazom, s kutom mlaza 110^0, izrađene od četiri različite vrsta materijala. Mlaznice s lepezastim spljoštenim mlazom su najčešće korišteni tip mlaznica na prskalicama u ratarskoj proizvodnji u Hrvatskoj. Relativno trošenje otvora mlaznice izrađenih od različitog materijala, značajno je variralo s vremenom uporabe mlaznice, izraženo u radnim satima. Na kraju perioda testiranja utvrđeno je da su mlaznice izrađene iz otvrdnjenog nehrđajućeg čelika bile najotpornije na trošenje, a slijedile su ih mlaznice od nehrđajućeg čelika, plastične, te mlaznice izrađene iz mjedi (mesinga). Ispitivanjem je utvrđeno da su se mlaznice s manjim nazivnim kapacitetom (količina protoka tekućine kroz mlaznicu, l/min), trošile brže u usporedbi s mlaznicama većeg nazivnog kapaciteta. Mjerenjem izlaznog kuta mlaza utvrđeno je da je povećanje količine protoka mlaznice uslijed trošenja njezina otvora korespondiralo sa smanjenjem kuta mlaza. Ispitivanje ujednačenosti površinske raspodjele tekućine obavljeno je na ispitnom stolu. Utvrđene su male razlike u ujednačenosti poprečne raspodjele između novih i trošenih mlaznica. Ipak, trošene mlaznice su dale veći volumen tekućine u centru mlaza u usporedbi s novim mlaznicama.

Ključne riječi: mlaznice, trošenje, materijal mlaznice, mlaz, kut mlaza, lepezasti mlaz

INTRODUCTION

Due to increasing concern about environmental pollution and crop production costs, it is essential to apply pesticides properly. Most pesticides are diluted and then applied with boom sprayers through a hydraulic nozzles. The hydraulic nozzles although being quite simple in design are very complex in its action on the fluid. The nozzles performs two basic functions. It meters the amount of liquid sprayed and atomises the fluid to form spray distribution pattern with a wide range of droplet size. The orifice size determines the flow rate (l/min) and influences the droplet size distribution.

Nozzles with smaller orifices produce smaller droplets. The nozzle design will influence spray pattern and also width of the spreaded fan. The typical spray angle for flat fan nozzles is either 110^0 or 80^0. The orifice of the nozzle tip is enlarged during use by the combined effects of the spray liquid's chemical action and the abrasive effect of particles, which may be the inert filler in wettable powder formulations or, foreign matter suspended in the spray. This is refferred to as nozzle wear or nozzle-tip erosion and results in vital functional parameters of spray such as an increase in droplet size and an alteration in spray pattern.

Changes in these functions of nozzle can influence the effectiveness of chemicals applied. Sprayer testing and calibration carried out on many farms in Croatia showed that over 50 percent of tested sprayers have had increased flow rate that could result in over use of pesticide. The main reason for overapplying was worn nozzles. Agricultural spray nozzles are made from a variety of materials including brass, stainless steel, hardened stainless steel, nylon, plastic and ceramic. Nozzles made from different materials have different wear characteristic. Other factors which affect nozzle orifice wear include shape and size of orifice, spraying pressure, usage time and type of formulation applied.

There has not been enough investigation about the influence of nozzle wear on spray distributions and droplet size spectrum. The objectives of this investigations were to determine the effect of nozzle material on orifice wear of flat fan nozzles and also effect of nozzle orifice wear on flow rates and spray distribution pattern.

MATERIAL AND METHODS

The nozzles selected for this investigations delivered flat fan patterns with 110^0 fan angle. Investigated nozzle were with nominal flow rates of about 0.78 , 1.4, 2.2 and 3.0 l/min at 300 kPa pressure. Tip materials were hardened stainless steel, stainless steel, plastic and brass. All selected nozzle were produced from Spraying Systems Company, USA. Five nozzle tips of each type were randomly selected. Initial flow rate, spraying angle and spray pattern characteristic of selected tips were determinet from original manufacturer data, before subjecting them to a standard wear process.

The spray distributions patterns measurement and flow rate test were carried out firstly on new, unworn nozzles. After that nozzles were subjected to a wear process by mounting them at boom sprayer. Manufacturer of sprayer was Agromehanika, Kranj with 12 meter boom width and 800 liter tank. This sprayer made completely seasonal spraying in winter wheat, winter barley and sugar beet. Nozzles constructed of different materials, but with same nominal capacity, were tested at the same time.

Flow rate tests

The flow rate of nozzles was determined by collecting the liquid delivered over a period of using time. Tests were done using measuring glass of 2000 cm^3 volume, with scale of 10 cm^3. The flow rate tests were carried out with clean water at the operating pressures of 300 kPa. The working pressure was controlled by a precision pressure gauge with a diameter of 0,15 m and measuring scale of 1,2 Mpa.

Tests to measure the increase in flow rate due to wear were stopped when there was about 10 % increase in flow rate through stainless steel tips. Tests with brass tips were terminated before other tips because the brass tips wore faster than the other nozzles tips material nozzles.

Spray pattern tests

Various paternators have been designed to measure the distributions of liquid by individual or groups of nozzles. Ozkan and Ackerman (1992.) measured the spray distributions patterns of new and worn nozzles with a computerized spray pattern analysis system.

In this study the spray distributions patterns of new and worn nozzles were measured with a patternator consisting of a metal tray corrugated so that the width of each channel is 5,0 cm. The nozzles were mounted 50 cm above the patternator table and liquid is collected in a sloping section which drains into calibrated collecting tubes at the ends of the channels. In this investigations patternator was positioned under a tractor boom to investigate variation in spray distribution along boom lenght. During all tests a 300 kPa spray pressure was maintained.

RESULTS AND DISCUSSION

Effect of nozzle wear on flow rate

Table 1 shows tip numbers, materials, the number of hours the tips were subjected to wear tests, and percent flow rate increase at the end of the test. The percent flow rate increase values are the average for the five nozzles tested in each group of nozzles with the same material and capacity.

Table 1. Percent increase in flow rate of worn nozzles (Time of use in hours is given in parenthesis)

Tablica 1. Postotak povećanja količine protoka trošenih mlaznica (U zagradama je vrijeme trošenja mlaznica u satima)

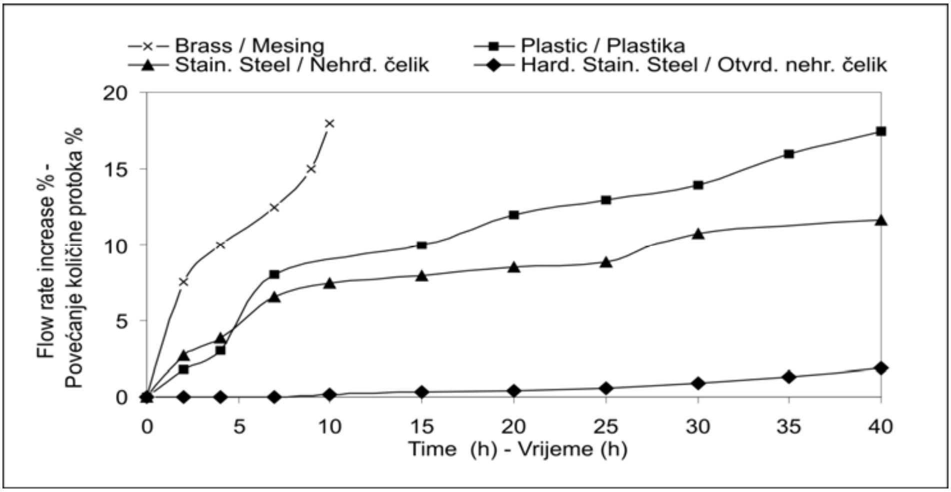
Tip Material Vrsta materijala	Nominal flow rate (l/min) Nazivni kapacitet (l/min)			
	0.78	1.4	2.2	3.0
Brass / Mesing	18.0 (10)	19.4 (40)	21.0 (80)	22.4 (100)
Plastic/ Plastika	8.5 (10)	8.0 (40)	8.2 (80)	12.2 (100)
Stainless steel/ nehrđajući čelik	3.5 (10)	3.7 (40)	4.1 (80)	4.3 (100)
Hardened stainless steel/ Otvrdnjeni nehrđajući čelik	0.3 (10)	1.6 (40)	1.9 (80)	2.1 (100)

Graph 1 shows the flow rate changes with time for several tip materials with nominal flow rates for new tips of 0,78 l/min. Similar results were obtained from tests using nozzle tips with nominal capacities of 1,4 ; 2,2 and 3,0 l/min. Each marker on the curves represents the mean value for five tips. For all capacities, the flow rates of brass tips increased more rapidly with time of use than with any of the other materials. Also, for all capacities tested the flow rates of hardened stainless steel tips increased less with time than with any of the other materials. The curves for flow rate increase with time for plastic tips were always between the curves for brass and stainless steel. At the end of all of our test the percent flow rate increase for plastic tips was greater than for stainless steel tips.

For all nozzle capacities, the stainless steel tips had average use times 4,8 times longer than brass tips before their flow rates increased ten percent. A comparison of stainless steel and plastic tips indicates that the stainless steel tips had longer use times for 0.78 and 3.0 l/min nozzle capacities, but the plastic tips had longer use times for the 1,4 and 2,2 l/min nozzle capacities before flow rate increased ten percent.

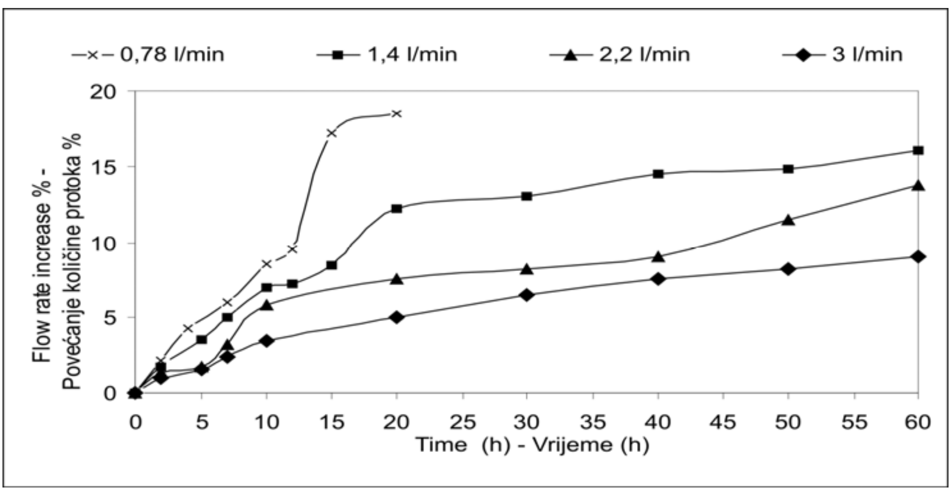
Graph 1. Effect of tip material on wear rates of nozzles orifice with nominal flow rate of 0,78 l/min

Grafikon 1. Utjecaj vrste materijala na trošenje otvora mlaznice za nazivni kapacitet 0,78 l/min



Graph 2. Effect of nozzle capacities on wear rate of nozzles with brass tips

Grafikon 2. Utjecaj kapaciteta mlaznice na trošenje, za mlaznice izrađene iz mesinga



Graph 2 shows the effects of time of use and nozzle capacity on flow rate increase for brass tips. Similar data were obtained for nozzle tips constructed of plastic, stainless steel and hardened stainless steel. The tests indicate that the brass tips, especially the smaller nominal capacities wore rapidly. Graph 2 shows that brass tip have had 17 percent flow rate increase after only 15 hours of use with nominal flow rate of 0,78 l min^{-1}.

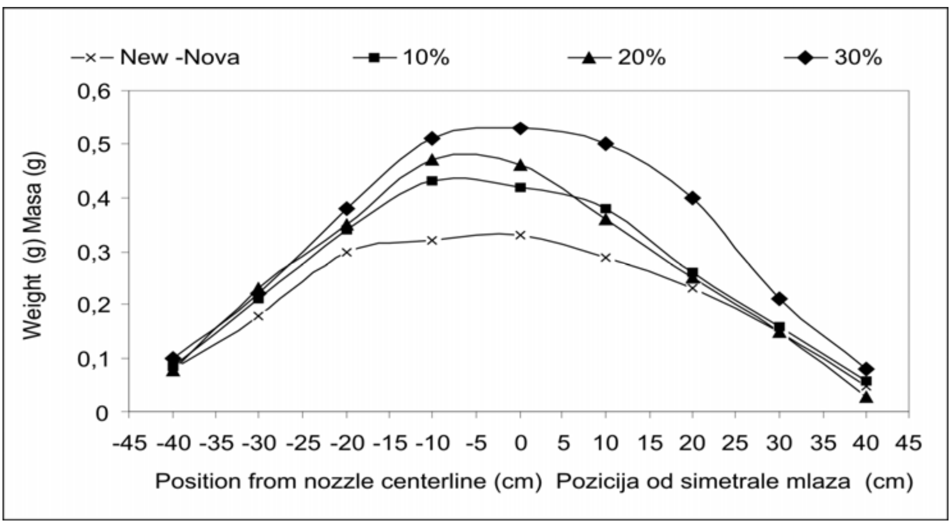
Effect of nozzle wear on spray pattern

Spray distribution patterns in this tests were measured with paternator with working width of 6,0 m .Paternator consists of a metal tray corrugated so that the width of each channel is 5,0 cm. The nozzles were positioned 50 cm above the patternator table.

Graph 3. shows spray patterns of new brass nozzles with initial capacities of 0,78 l/min and worn nozzles from same material with flow rates 10, 20 and 30 % greater than new nozzles.

Graph 3. Spray patterns of a new 0,78 $lmin^{-1}$ capacity brass nozzle, and worn brass nozzles with flow rates 10, 20, and 30 % greater than that of the new brass nozzle.

Grafikon 3. Ujednačenost raspodjele tekućine nove mesingane mlaznice nazivnog kapaciteta 0,78 $lmin^{-1}$ i trošene mesingane mlaznice istog nazivnog kapaciteta, povećanog protoka u odnosu na nazivni za 10, 20 i 30 %.



The results of spray pattern tests generally indicate that, for the nozzles and amount of wear tested, there was little difference in the widths of spray deposit patterns of new and worn nozzles. However, worn nozzles delivered greater flow rates in the centers of the patterns than at the edges of the patterns.

CONCLUSIONS

The relative wear rates of nozzle tip materials can vary greatly with differnt time of use. For all nozzle flow rates, the stainless steel tips had average use times 4,8 times longer than the brass tips, before flow rates increased ten percent. For all materials and nominal capacities tested, the flow rates of brass and hardened stainless steel tips increased the greatest and least amounts, respectively, with time of use. The flow rates of some plastic tips decreased slightly with time of use before beginning to increase.

For any percentage flow rate increase, greater nozzle nominal capacity results in greater usage time. Regarding the effect of nozzle wear on spray pattern, there was little difference in the widths of spray deposit patterns of new and worn nozzles. However, there were greater differences between new and worn nozzles in volumes of liquid collected in the centers of the patterns than at the edges of the patterns.

REFERENCES

1. ASAE Standars, 38th Edition (1991): Procedure for measuring sprayer nozzle wear rate. Trannsactions of the ASAE. St. Joseph, MI, USA.
2. Duvnjak, V. (1998): Effect of orifice wear of flat fan nozzles on flow rate and droplet size distributions. Actual tasks on agricultural engineering. Proceedings from 26th International symposium on agricultural engineering, Opatija, Croatia, 1998. 281-288.
3. Duvnjak, V., Banaj, Đ., Zimmer, R., Jurišić, M. (1999): Contribution of a field sprayer testing to safer, more effective spraying in Croatia. Actual tasks on agricultural engineering. Proceedings from 27th International symposium on agricultural engineering, Opatija, Croatia, 1999. 147-156.
4. Heinkel, R., Fried, A., Lange, E. (2000): The effect of air injector nozzles on crop penetration and biological performance on fruit sprayers. Aspects of Applied Biology. 57: 301-307.

5. Knewitz, H., Koch, H., Fleischer, G., Lehn, F. (2002): Effect of coarse and fine droplet application on pesticide deposition in orchards. Gesunde Pflanzen. 54-5: 141-145.
6. Langenakens, J., De Moor, A., Taylor, W.A., Cooper, S., Taylor, B. (2000): The effect of orifice wear on flat fan nozzle performance: using predictive and dynamic techniques to determine quality of liquid distribution. Aspects of Applied Biology. Associations of applied biologist, Warwick, UK, 11 pp.
7. Miller, P.C.H., Lane, A.G. (1999): Relationship between spray characteristic and drift risk into field boundaries of differnt structure. Aspects of Applied Biology 45: 45-51.
8. Ozkan, H.E., Reichard, D. L., Ackerman, K. D. (1992): Effect of orifice wear on spray patterns from fan nozzles. Transactions of the ASAE, USA, 35, 1091-1095.
9. Reichard, D.L., Ozkan, H.E., Fox, E.D. (1991): Nozzle wear rates and test procedure. Transactions of the ASAE, USA, 1095-1102.

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Primljeno – Received:
30.09.2009.