

Study on the Nozzles Wear in Agricultural Hydraulic Sprayer

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Abstract – The aim of the current study was to investigate some factors affected on the sprayer flow rate and nozzle wears includes spraying pressure, duration of test, type of nozzles. The current research conducted in the laboratory of agricultural engineering department, faculty of agricultural kafr el sheikh university, Egypt. Five different types of nozzles were used under three different operating pressure 150 kPa, 220 kPa and 370 kPa. The time operating tests carried out at 0 h, 48 h, 120 h, 180 h and 240 h. The nozzle wear value for the Tip ceramic AD120-04 nozzle was 10.2 % at maximum operating pressure 370 kPa and after 240 h duration operation time. The increasing of duration operation time test of the different nozzles tips tends to increase the nozzle wears. The ceramic AD120-04 nozzle gave the low values of nozzle wear compared to LU90-03, LU90-05, ST110-04 and ES90-04 nozzles at all operation time and three operating pressures. The nozzle wears value after 48 h was 3.8 % for ES90-04 at 370 kPa operating pressure. The nozzle wears value after 240 h were 15.45 %, 15.8 %, 10.2 %, 14.8 % and 16.05 % for LU90-03, LU90-05, AD12-04, ST110-04 and ES90-04 at 370 kPa operating pressure respectively. Brass ES 90-04 nozzle gave the maximum nozzle wears after 240 h duration time. The nozzle wear for ES 90-04 brass nozzle were. 12.7 %, 13.95 % and 16.05 % at 150 kPa, 240 kPa and 370 kPa operating pressure respectively.

Keywords – Nozzle Wears, Flow-Rate.

I. INTRODUCTION

Avery large portion of pesticides are applied with sprayers through hydraulic pressure nozzles. Nozzles of many different types, capacities and materials are used to apply pesticides. Since nozzle orifices greatly influence application rate, it is important to know the wear rates of nozzle orifices. There has been considerable interest in nozzle wear rates and there are several publications regarding the wear rates of various nozzles for different operating conditions. Research on nozzle wear has concentrated on the change in flow rate (Ozkan et. al., 1992a, Ozkan et. al., 1992a, Zhu et. al., 1995a ; Zhu et. al., 1995b and Reichard et al. 1991). 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. Reichard et al. (1991) found that the smaller the nozzle orifice, the shorter the time of the nozzle wear. Reed and Ferrazza

(1984) reviewed the results of nozzle wear tests conducted by several different researchers. The results were presented by a wear number defined as the relative wear life of a spray tip material using brass as reference. Brass was given a wear number equal to 1. A comparison of the relative wear between brass and stainless steel fan tips by five different researchers revealed a range of wear numbers from no difference in wear life to stainless steel lasting 19 times longer than brass. Novak and Cavaletto (1988) conducted wear tests using a definite herbicide (atrazine) and different fan tips. Their tests with 0.76 dm³/min flow rate (operated at 276 kPa) indicated operation times of 100, 200, and 400 hours before 10% increase in flow rate for brass, nylon, and stainless steel tips, respectively. The literature on nozzle wear rates indicates considerable differences among reported results. Generally the difference in nozzle wear rate is due to the different operating conditions used when testing nozzles. Factors influencing nozzle wear include spraying pressure, duration of test, type and concentration of materials used in the spray mixture, time of use of abrasive before it is changed during the test, type of nozzle, and size, shape, and the material of the orifice. There is considerable need for reliable information the wear rate of an 8001 brass fan spray tip was greatly influenced by spray pressure. For example, the relative wear life was five times longer at 138 kPa than at 414 kPa. A comparison of relative wear between 8001 stainless steel and brass fan spray tips showed that stainless steel had 9.5 times longer life when the operating pressure was 138 kPa, but only 4.0 times longer life when operated at 414 kPa. Spray nozzle tips are made from a variety of materials including brass, stainless steel, and hardened stainless steel, nylon, plastic and ceramic and have different wear characteristics. Other factors which effect orifice wear include the shape and size of the orifice, spraying pressure, operation time, and type of chemical formulation applied. Friesen (1984) conducted tests in the laboratory to evaluate the wear characteristics of ten different nozzle types and sizes. Tip materials included brass, stainless steel, ceramic and nylon. Spray patterns delivered by each nozzle were measured with new and used nozzle tips. He reported that no definite conclusions were found regarding the relationship between maximum allowable increases in output versus acceptable nozzle patterns. However, it appeared that an increase of 15% in flow rate did not cause any considerable change in the spray pattern. Ohrn et al. (1991) measured changes in discharge coefficient due to wear for 40 disks with circular orifices. They concluded that shape of orifice inlets and operating conditions had greater effect on the discharge coefficient than either

thickness/diameter ratios of the orifices or Reynold's number. Reichard et al. (1991) developed polynomial equations to fit flow rate increase due to wear with various nozzle capacities (0.76, 1.51, 2.27 and 3.03 L/min) and materials (brass, stainless steel, nylon and hardened stainless steel). They indicated that the percentage increases in flow rates for brass, stainless steel, and nylon tips varied with the square root of the operation time. Although some nozzle manufacturers recommend the replacement of new nozzle when the increase in flow rate of a worn nozzle is greater than the flow rate of the new one, if the difference is higher than 10 %. However, the majority of the users tend to use nozzles longer. Both the user and manufacturer of nozzles will benefit from the better prediction of flow rate changes with the operation time. Nozzle wear rates are influenced by pesticide formulation, nozzle type, orifice material and capacity and operating pressure used when applying pesticides. In addition, Gajtkowski (2000b) also includes a good quality of spray requires using technically efficient plant protection equipment, especially nozzles which do not show excessive wear degree. 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). It is generally accepted to replace nozzles when the liquid flow rate has increased by 10% in relation to the catalogue data. 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). Koszel . (2009) indicated that 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. 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.

II. OBJECTIVES

The objectives of this research were to develop a laboratory standard method for measuring the wear rate of nozzles and to determine the relative wear rate of fan spray tips constructed of various nozzles materials under Egyptian conditions. As well as, to investigate the some factors affected on nozzle wears and the sprayer flow rate.

III. MATERIALS AND METHODS

The nominal spray pressures were 150 kPa, 240 kPa and 370 kPa during the tests. Water flow rate through each nozzle was measured periodically with a digital balance type 'G&G' with 1% accuracy. A mixture containing 0.06 kg of kaolin clay per liter of water (Zhu et al. 1995) was used for testing all of the nozzles. The type of kaolin clay used is similar to carriers that have been used in wet-able powder pesticide formulations. Due to the wear resulting

from the abrasives, the mixtures were always changed at times. The new nozzles tip types LU90-03, LU90-05, AD120-04, ST110-04 and ES90-04 were used and tested at 150 kPa, 240 kPa and 370 kPa operating pressures. The treatments were tested at 0 h, 48 h, 120 h, 180 h and 240 h operating time. The components of the laboratory nozzle wear system consisted of the pressure gauge manometers, water tank 200 l, and water pump 0.6 kW, valve and regular pressures as shown in figures 1 & 2. The new nozzles tip types LU90-03, LU90-05, AD120-04, ST110-04 and ES90-04 lechler Co., Germany were set up at two pipe end of output line of the water pump and fixed into the tank. The operating pressures were adjusted at the above mentioned spraying pressure by the regular valve.

Procedure and measurements

The experiments were performed using the supply system of nozzle wears that constructed in the laboratory of agricultural engineering dept., kafr El Sheikh University. The main treatments for the current study were tips of nozzle materials, duration time test and nozzles operating pressure. Three replications were used for every treatment to obtain a high accuracy analysis of results. The arrangement and statistical analysis of the experiments was according to randomize completely design. The control valves were used to adjust the 150 kPa, 240 kPa and 370 kPa operating pressure which produced from the water pump. The regulated cylinder was fixed under each nozzle to collect the samples.

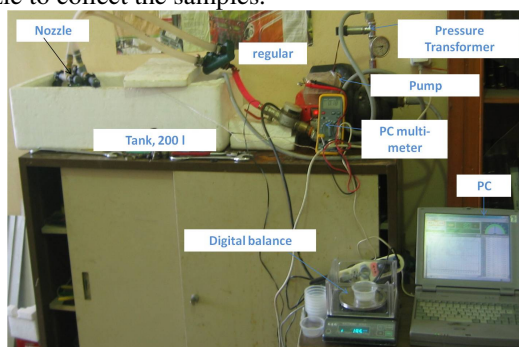


Fig.1. Display the nozzles wear laboratory test system.

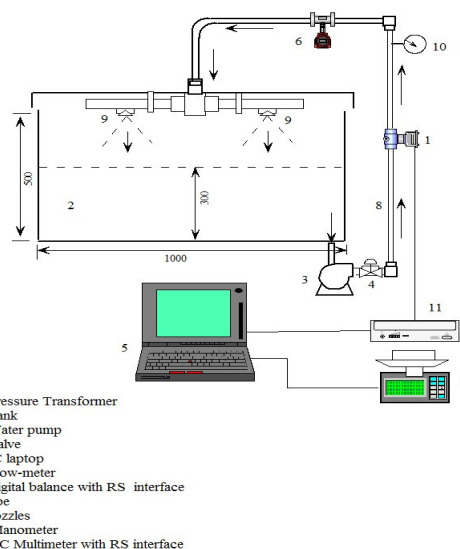


Fig.2. Display the diagram of the nozzles wear laboratory test system.

The control samples were operated without kaolin for 240 h operation time test. 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. The equation 1 was used to calculate the increasing of flow-rate or degree of nozzle wear. As well as, the flow rate from each nozzle was measured at every treatment. The sample from each nozzle was collected and weighted to measure weight flow rate. The time of collecting sample at every treatment was 2 min. The flow rate for each nozzle under every treatment conditions were measured and recorded after every duration test or operation time 0 h, 48 h, 120 h, and 240 h.

$$F_w = \left(\frac{F_t - F_0}{F_0} \right) \times 100 \dots \dots \dots (1)$$

F_w Increasing of flow-rate or nozzle wears, %
 F_t flow-rate after number of hour's operation time, $l \text{ min}^{-1}$
 F_0 flow-rate for control or after zero hour operation time, $l \text{ min}^{-1}$

IV. RESULTS AND DISCUSSIONS

The result of the current research presented that the increasing of duration operation time test tends to increase the flow-rate and nozzle wears under all treatment conditions. As well as, the increasing of the operating pressure tends to increase of flow-rate as shown in table 1., The flow-rate at 370 kPa and 240 hour duration operation time were 1.25 l min^{-1} , 1.83 l min^{-1} , 1.59 l min^{-1} , 1.81 l min^{-1} and 1.40 l min^{-1} for LU90-03, LU90-05, AD120-04, ST110-04 and ES90-04 nozzles respectively. The increment flow-rate values after 240 h duration operation time at 370 kPa operating pressure were 0.17 l min^{-1} , 0.25 l min^{-1} , 0.15 l min^{-1} , 0.23 l min^{-1} and 0.19 l min^{-1} for LU90-03, LU90-05, AD120-04, ST110-04 and ES90-04 nozzles respectively.

Effect of operating pressure on nozzles wear

Figure 3 illustrate the effect of the operating pressure on the increasing of flow-rate (nozzle wear rate) for different nozzles and 240 h duration time. The Tip ceramic AD120-04 nozzle gave the low nozzle wear compared to LU90-03, LU90-05, ST110-04 and ES90-04 nozzles at maximum operating pressure 370 kPa. The nozzle wear rate value for the Tip ceramic AD120-04 nozzle was 10.2 % at maximum operating pressure 370 kPa and after 240 h duration operation time. The ceramic AD120-04 nozzle wears after 240 h duration time were 8.45 %, 9.85 % and 10.2 % at 150 kPa, 240 kPa and 370 kPa operating pressure respectively. On the other hand brass ES 90-04 nozzle gave the maximum nozzle wears after 240 h duration time. The nozzle wear for ES 90-04 brass nozzle were. 12.7 %, 13.95 % and 16.05 % at 150 kPa, 240 kPa and 370 kPa operating pressure respectively. As well as, figure 4 illustrate the effect of the operating pressure on nozzle wear or increasing of flow-rate for different tips of

nozzles at 48 h duration time. A comparison of relative wear between low operating pressure 150 kPa and maximum pressure 370 kPa for all different nozzles showed that less different time longer life for all nozzles at 240 h duration test.

Effect of duration test and tips of nozzles on nozzles wear

Figures 5, 6 and 7 display the effect of the duration test (operation time) on the increasing of flow-rate for different tips of nozzles at three different operating pressures. Generally, the increasing of duration test of the different nozzles tips tends to increase the nozzle wears. The ceramic AD120-04 nozzle gave the low values of nozzle wear compared to LU90-03, LU90-05, ST110-04 and ES90-04 nozzles at all operation time and three operating pressures. Both ceramic AD12-04 nozzle and Stainless steel ST110-04 produced a good degree nozzle wear compared to the plastic nozzles LU90-3 and plastic nozzle LU90-5; and brass nozzle ES90-04 at 240 h operation time. This result is agreement with Reichard et al. (1991). It is clearly that after 48 h duration test or operation time, the nozzle wears may be increasing by increasing of operating pressure. The nozzle wears after 48 h test operation time was less than 4 % for all Tip nozzles under maximum operating pressure. The nozzle wears value after 48 h were 3.0 %, 2.75%, 2.7%, 3.5 % and 3.8% for LU90-03, LU90-05, AD12-04, ST110-04 and ES90-04 at 370 kPa operating pressure respectively. On the other hand, the nozzle wears value after 240 h were 15.45 %, 15.8 %, 10.2 %, 14.8 % and 16.05 % for LU90-03, LU90-05, AD12-04, ST110-04 and ES90-04 at 370 kPa operating pressure respectively. The degrees of nozzle wear at 150 kPa operating pressure for AD120-04 nozzle were 1.6 %, 5.85 % 6.2 % and 8.45 % after 48 h, 120 h, 180 h and 240 h operation time respectively. Also, the degrees of nozzle wear for ES120-4 nozzle at 150 kPa operating pressure were 3.1 %, 5.8 %, 9.7 % and 12.7 % after 48 h, 120 h, 180 h and 240 h operation time respectively.

The degrees of nozzle wear at 370 kPa operating pressure for AD120-04 nozzle were 2.2 %, 7.35 % 9.05 % and 10.2 % after 48 h, 120 h, 180 h and 240 h operation time respectively. Also, the degrees of nozzle wear for ES120-4 nozzle at 370 kPa operating pressure were 3.8 %, 8.8 %, 12.9 % and 16.05 % after 48 h, 120 h, 180 h and 240 h operation time respectively.

A comparison of relative wear between minimum duration test 48 h and 240 h for all different nozzles showed that minimum duration test 5 times longer life for LU90-04 nozzle, but only 3.0 times longer life for AD120-04 nozzle when operated at 370 kPa. As well as, the duration test gave a high significant effect on the nozzle wear. In addition, the material of nozzle gave high significant effect on nozzle wear.

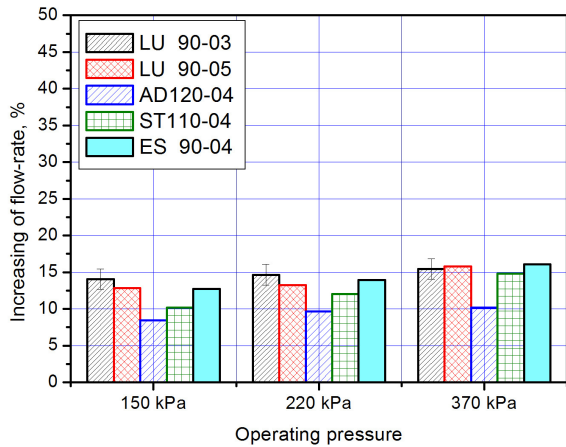


Fig.3. Indicate the effect of operating pressure on nozzle wear (flow-rate percent) for different tip nozzles after 240 h operation time.

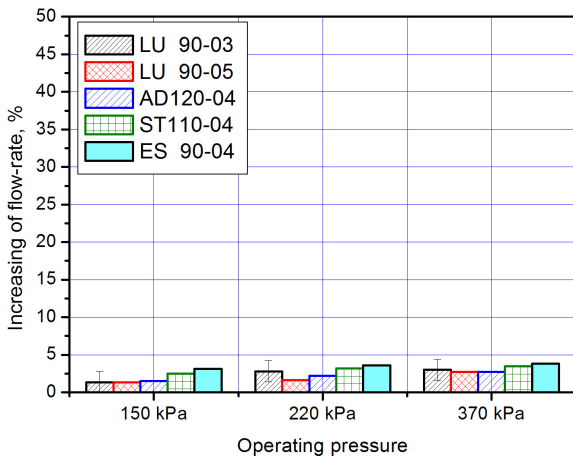


Fig.4. Indicate the effect of operating pressure on nozzle wear (flow-rate percent) for different tip nozzles after 48 h operation time.

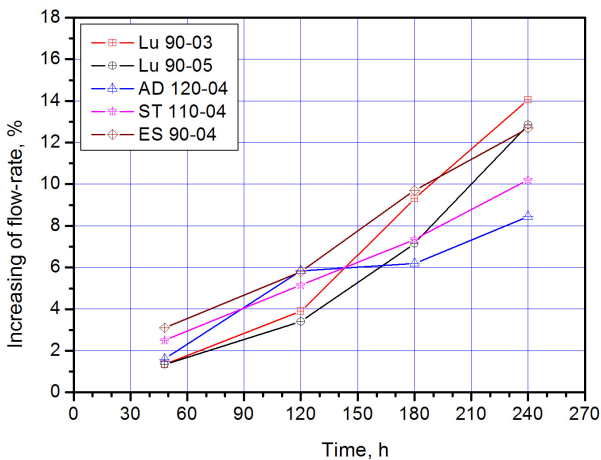


Fig.5. Indicate the effect of operation time on nozzle wear (flow-rate percent) for different tip nozzles at 150 kPa.

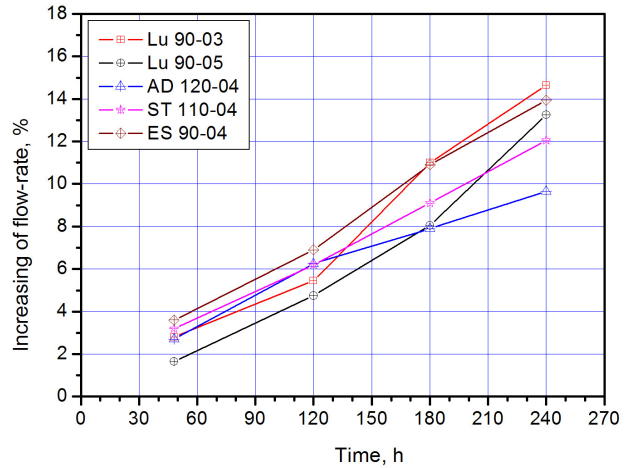


Fig.6. Indicate the effect of operation time on nozzle wear (flow-rate percent) for different tip nozzles at 220 kPa.

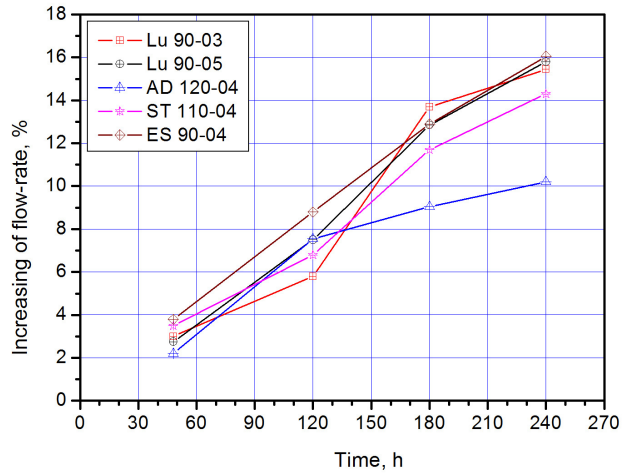


Fig7. Indicate the effect of operation time on nozzle wear (flow-rate percent) for different tip nozzles at 370 kPa.

V. SUMMARY AND CONCLUSION

The result indicated that, both ceramic AD12-04 nozzle and Stainless steel ST110-04 produced a good degree nozzle wear compared to the plastic nozzles LU90-3 and plastic nozzle LU90-5; and brass nozzle ES90-04 at 240 h operation time. On the other hand brass ES 90-04 nozzle gave the maximum nozzle wears after 240 h duration time. The nozzle wear for ES 90-04 brass nozzle were. 12.7 %, 13.95 % and 16.05 % at 150 kPa, 240 kPa and 370 kPa operating pressure respectively. Also, the degrees of nozzle wear for ES120-4 nozzle at 370 kPa operating pressure were 3.8 %, 8.8 %, 12.9 % and 16.05 % after 48 h, 120 h, 180 h and 240 h operation time respectively. As well as, it may able to measure the wear nozzle by using the laboratory system test under Egyptian condition. We recommended measuring the nozzle wear test after every 120 h operation time. As well as, using the stainless steel or ceramic nozzle and operating at low operating pressure for the other material of nozzles.

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Table 1: Display the flow-rate for different nozzles at three operating pressure and different duration time test.

Type of nozzles	Pressure, kPa	Flow-rate, l min ⁻¹					differences*
		Control	48h	120 h	180 h	240 h	
Lu 90-03 (POM)	150	0.84	0.85	0.87	0.92	0.96	0.12
	220	0.97	1.00	1.02	1.08	1.11	0.14
	370	1.08	1.11	1.14	1.23	1.25	0.17
Lu 90-05 (POM)	150	1.39	1.41	1.44	1.49	1.57	0.18
	220	1.61	1.64	1.69	1.74	1.82	0.21
	370	1.58	1.62	1.70	1.78	1.83	0.25
AD 120-04 Ceramic	150	1.12	1.14	1.19	1.19	1.21	0.09
	220	1.29	1.33	1.37	1.39	1.41	0.12
	370	1.44	1.47	1.55	1.57	1.59	0.15
ST110-04 S. steel	150	1.29	1.32	1.36	1.38	1.42	0.13
	220	1.44	1.49	1.53	1.57	1.61	0.17
	370	1.58	1.64	1.69	1.76	1.81	0.23
ES 90-04 brass	150	0.91	0.94	0.96	1.00	1.03	0.12
	220	1.12	1.16	1.20	1.24	1.28	0.16
	370	1.21	1.26	1.32	1.37	1.40	0.19

*different between control and flow-rate after 240 h operation time