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SRAYING WITH ROsá CENTRIFUGAL ATOMIZERS

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Slit-type nozzles are becoming the things of the past. The future of chemical crop protection lies with ROsá centrifugal atomizers developed in Ukraine [1]. The name 'Rosá' (meaning 'dew') comes from the Ukrainian phrase '**R**ozpylennya with **osa**zhdeniem' – "spraying and deposition." The Rosá atomizers endow spraying operations with novel qualities, which cannot be attained with slit-type nozzles. The key advantages are enhanced efficiency, reliability and safety in spraying. With the power consumption twice less than that required by slot-type nozzles, the ROsá atomizers are capable to provide dispersity of droplets less than 350 μm in size and perform forced precipitation of the atomized fluid by the air stream entrapped into the spray jet. An acceptable travel speed limit in spraying is up to 30 km / h at a wind velocity up to 9 m/s. The useful operating life of the ROsá atomizers is more than 7,000 hours.

For more than ten years, we have conducted extensive studying and computer modeling of the ROsá atomizer performance on the test benches and in sprayers. In this series of articles we would like to introduce readers to the results obtained by us.

We have developed the ROsá atomizers for low-capacity spraying of field crops, and we hope you will take advantage of these advances to the fullest.

Part 1. The ROsá centrifugal atomizer

<u>1. Design and Operation principle</u>. Fig. 1 shows a general view and a principal design arrangement of the ROsá atomizer. The atomizer consists of the body 1, the nozzle 2, the swirl core 3 and the rubber ring 4.

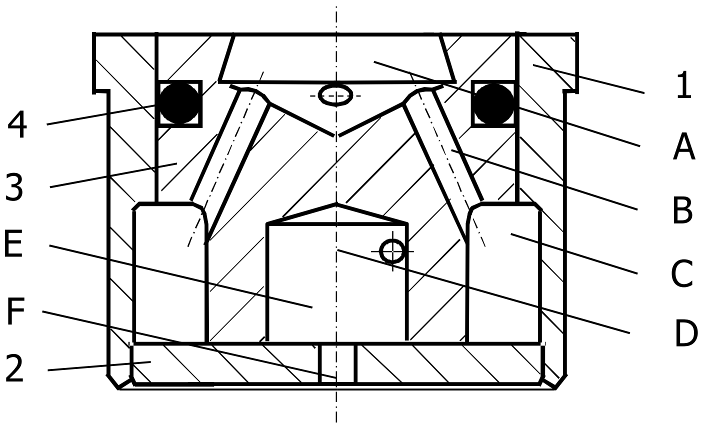

Fig. 1. General view and principal design arrangement of the ROsá atomizer.

The fluid from the distributor A via channels B gets into the ring in the reservoir C and through the tangential input channels D the fluid flows into the swirl chamber E. Here, the fluid is set on a rotary motion and forms a stable vortex structure consisting of vortex threads, which subsequently determine the sizes of droplets. After passing through the nozzle outlet F, the vortex threads disintegrate into droplets and form a hollow cone jet pattern. The body and the nozzle in the ROsá atomizers are made of stainless steel and the swirl core is made of brass.

For comparison, Fig. 2 shows a conventional slit-type nozzle having a plastic body with an insert, the latter may be made of polymeric materials, stainless steel or ceramics [2]. An individual filter is provided at the inlet of the atomizer. Dispersity, spray angles of the pattern and flow rates in slit-type nozzle are determined by the shape and size of the orifice.

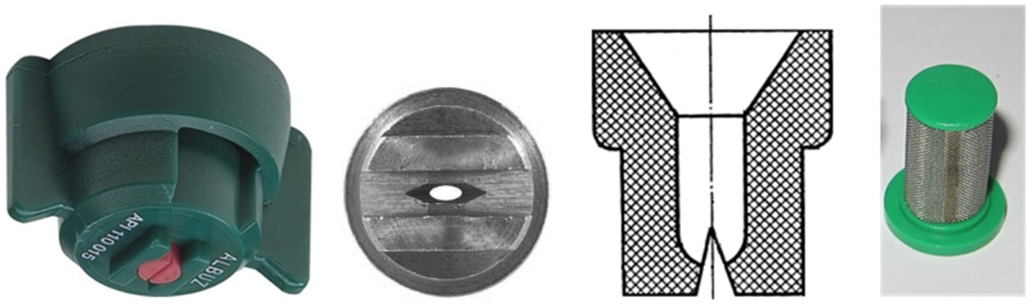

Fig. 2. General view and principal design arrangement of the slit-type nozzle and the filter.

People have been paying too high a price for the primitive "slit-type" approach to the problems of pesticides spraying. It entails environmental pollution, food products contamination, and excessive costs of pesticide overconsumption due to rapid wear on the nozzle orifice, cumbersome designs of spraying installations, and insufficient safety in their maintenance.

Due to its sophisticated design, the ROsá centrifugal atomizer ensures control of motion of the fluid mixture and the ingredients contained therein, it enhances dispersion and induced deposition of the atomized fluid; thereupon the hydro-homogenization of pesticide is performed immediately in the atomizer. All of these improve the operational characteristics and techno-economic indicators of spraying, moreover, the atomizer nozzles do not get clogged or worn.

2. <u>Capacity of nozzles</u>**.** ROsá centrifugal atomizers are spaced 0.5 m apart on the sprayer boom and provide the flow rates of the working fluid according to capacities of individual nozzles as specified in the Table 1.

Table 1

Capacity of nozzles, L/ha

Atomizer ROsá	Pressure, MPa	Capacity, one nozzle, L/min	The speed of the sprayer, km/h								
			5	**8**	**10**	**12**	**14**	**16**	**20**	**25**	**30**
P.03.0.3	**0,3**	**0,30**	**72**	**45**	**36**	**30**	**26**	**23**	**18**	**14**	**12**
P.03.0.6		**0,60**	**144**	**90**	**72**	**60**	**51**	**45**	**36**	**29**	**24**
P.03.1.2		**1,20**	**288**	**180**	**144**	**120**	**103**	**90**	**72**	**58**	**48**

Note: The designation of a series of atomizer R.03, such R.03.0.6: R - atomizer, 03 - nominal pressure - 0.3 MPa, 0.6 – capacity of one nozzle in L/min.

According to European standard EN 12761-2, the capacity value in a nozzle should not deviate more than ± 10 % of the tabulated value specified by the manufacturer and it should not exceed an average capacity of a set of nozzles by more than ± 5 %. Technical specifications TU U 29.3-31177688-002:2006 envisages the provision of control of capacity rates for all ROsá atomizers being manufactured. In the sets of atomizers supplied for sprayers, the deviation from the average capacity does not exceed 4 % for R.03.0.3, 3.5 % for R.03.0.6, and 1.75 % for R.03.1.2. Each set of nozzles is furnished with the manufacturer's certificate specifying the average capacity rate within the set.

TeeJet Co., the manufacturer of slit-type nozzles [2], warns the consumers of the need to check nozzles for wear and of the losses that may arise from the use of worn nozzle tips.

The nozzle tips of the ROsá atomizers are not prone to wear, their capacities and dispersity characteristics do not alter during the entire period of the sprayer's operation and therefore, there is no need to control flow rates.

3. Pressure. The nominal pressure of the working fluid in the ROsá atomizers is 0.3 MPa with a recommended deviation of ± 0,05 MPa. If the pressure differs from its nominal value, the flow rate of the fluid passing through the orifice varies according to the following relationship:

$$Q = Q_{nom}\sqrt{\frac{P}{P_{nom}}}, \tag{1}$$

Short-time operation of atomizers with a reduced pressure of 0.2 MPa and with an increased pressure up to 0.4 MPa is acceptable.

4. Spray angle. The ROsá atomizers have a spray angle of ≈ 90 °, which does not degrade in the pressure range from 0.2 to 0.4 MPa. This ensures stable bandwidth coverage in spraying the atomized fluid.

Slit-type nozzles have a tendency to alter their spray angle characteristics depending on the pressure and that, in turn, entails variations in the bandwidth of coverage. For example, in the 11002 spray nozzle model, a pressure increased from 0.1 MPa to 0.28 MPa results in the spray pattern angle expanded from 90° to 110°, and when the distance to the target surface is reduced to 0.46 m, the bandwidth of coverage expands from 0.92 to 1.31 m [2].

5. Droplet sizes. Injury to weeds and pests during spraying is the result of damage caused by the pesticide molecules to the plant cell metabolism. That is why, in an ideal scenario, it is best to perform spraying with the immediate pesticide molecules. But disintegration of fluids into molecules comes at a high price of energy consumption. For example, water disintegrates into molecules at a critical temperature of 374 °C and a pressure of 22 MPa. In general practice, spraying is carried out with the droplets of the spray mixture containing water and pesticide. At that, the droplet size should be small enough to give effective deposition and retention of the droplets on the surface being treated and not to exceed the allowable losses due to evaporation and wind drift. To reduce pesticide losses due to evaporation or drift and to meet the limits on environmental pollution set out in European Standard EN 12761-2, the number of droplets under 115 µm in size should not exceed 10 % of the total volume of fluid being sprayed. The slit-type nozzle 1102 model having the spray pattern angle of 110° and the nozzle capacity of 0.72 L/min under the pressure of 0.25 MPa complies with the above mentioned Standard. The same Standard does not extend to the sprayers that are equipped with the means that deter drift. The air entrapped into the spray pattern of the ROsá atomizer forcibly precipitates the atomized fluid, prevents its evaporation, restrains drift, and allows for a greater amount of fine droplets to be deposited.

For comparison, Table 2 presents the spectra of the droplet sizes (VMD) contained in 10 %, 50 % and 90 % of the volume of spray produced by the ROsá atomizers and by the slit-type nozzles at the comparable flow rates.

Table 2

Distribution of droplet diameters

Atomizer	Pressure, MPa	Capacity, one nozzle, L/min	Volume Median Diameters of Droplets (µm), %, less			The volume-surface diameter of d_{32}
			10 %	50 %	90 %	
			$D_{V0.1}$	$D_{V0.5}$	$D_{V0.9}$	
ROsá R.03.0.6	0,3	0,6	70	131	238	115
Lechler IDK 120-015			137	367	839	282
TeeJet XR 110015			93	200	330	
TeeJet TT 110015			158	296	563	
Lechler LU 120-02		0,78	88	183	314	164
ROsá F.03.1.0		1,0	77	150	264	137
TeeJet XR 11003		1,2	121	241	386	
TeeJet TT 11003			189	373	723	
Hardi ISO F 110 03			144	274	422	228
Hardi ISO Injet 110			324	537	689	465

The volume median diameter (VMD) of the $D_{V0.5}$ droplets with the ROsá atomizers is 1.5 times less than that with the slit-type nozzles and the maximum VMD value does not exceed 350 μm. Improved dispersion of pesticide spraying is a crucial factor for upgrading spraying efficiency.

6. Reliability**.** Because of blocking the channel cross-section in the slit-type nozzle (Fig.2), the mechanical admixtures in the working fluid tend to travel closer to the axis and that increases the risk of clogging of the orifice slit and threatens with the overall failure of the nozzle. The rims of the orifice exit are most vulnerable to clogging. To eliminate the risk of clogging in the orifice exit, the working fluid is subjected to multi-stage filtration. Only in case when a mesh size in an individual filter is at least three times less, or even smaller, than the width of the orifice, the filter is capable to prevent clogging in the nozzle. Clogging in the individual filter causes an increase in its hydraulic resistance and a pressure drop before the nozzle; as a consequence, the working fluid flow rate decreases. It is recommended [2] to clean the filter and the orifice exit with a soft bristle brush because even wooden toothpicks may damage the edges of the orifice. While cleaning the nozzle or the individual filter, the operator has to enter the area treated with the pesticide and manipulate the shut-off device that contains the working fluid. Therefore, maintenance of the slotted nozzles presents a hazard to human health.

Owing to the spatial motion of the working fluid inside the ROsá atomizer, its flow passages do not get clogged with solid particles. During the rotation of the flow under the action of centrifugal forces, the solid particles are thrust aside towards the wall and remain in the ring collector. The fluid passing through the ring collector causes the accumulated particles to wear against one another and as their size decreases, they are washed down and out through the exit channels of the swirl core. The orifice exit is also protected from clogging due to the fact that the action of the centrifugal force urges the solid particles to move from the axis towards the cylindrical wall of the swirl chamber. Thus, the design arrangement of the flow passages in the ROsá centrifugal atomizer provides effective protection from clogging and ensures its reliable, virtually faultless operation of the nozzle with single-stage filtering through a mesh of 300 μm.

Durability. In slit-type nozzles, the worn edges of the orifice may result in increased fluid flow rates, distorted spray patterns, and deteriorated dispersion. If the capacity rates deviate by more than 10% from reference values, the atomizer is considered to be unacceptable for further use. According to research conducted by SGS UK LTD, Saint-Gobain AC (France), it was established that with the application of 2.5 % solution of kaolin and water at the pressure of 0.275 MPa, the slit-type nozzles with the tips made of brass, stainless steel and polyvinylidenefluoride showed, respectively, operation times of 10, 30, and 40 hours before their flow rates exceeded by 10 % the reference values. After 50 hours of operation, the flow rates increased by 8 % in the nozzles with the polyacetal tips and by 5 % in the nozzles with the ceramic tips.

The designed service life of the ROsá centrifugal atomizers is no less than 7,000 hours and that is ample for 5 years of their operation in the sprayer.

It is known [3] that the action of solid particles results in wear of a certain volume of plastic material:

$$V = Kd^3U^3\sqrt{\left(\frac{\rho}{H}\right)^3}, \tag{2}$$

where V is the volume of plastic material, $K = \frac{F_N}{F_T}$ is the ratio of components of the normal force F_N to the tangent force F_T of solid particles, which exert their action on the surface of plastic material; d, U, ρ are a diameter, velocity, density of an individual solid particle and H is Vickers hardness. In contrast to a slotted nozzle having the value of the coefficient $K \approx 1$, in the ROsá atomizers the flow duct has $K \approx 0$ and only the swirl chamber has $K \approx 1$. Modeling the motion of the particles of Al_2O_3 in the swirl chamber [4] has shown that the particles larger than 200 μm in size move along the cylindrical wall surface and the particles less than 17 μm in size are entrained with the flow and discharged through the orifice, while the particles ranging from 17 μm to 200 μm in size settle down on the abut end of the wall and after that they are entrained with the near-wall flow and carried out from the chamber. Provided that total filtration is accomplished through a mesh of 300 μm, the solid particles of 200-300 μm in size induce wear in the cylindrical wall of the swirl chamber and carve an annular groove in the swirl core at the abut end of the nozzle; this groove has no effect either on the capacity rate or dispersion characteristics of the atomizer.

An increase in the annular velocity around the axis of the swirl chamber is accompanied with a pressure drop and initiates cavitation under the condition that

$$\frac{\rho W_*^2}{2} \rangle P_a - P_s, \tag{3}$$

where ρ is the density of the working fluid, W_* is the annular velocity; P_a is the atmospheric pressure; and P_s is the saturated vapor pressure in the working fluid.

For example, for water at t = 20 °C, P_s = 2331,8 Pa, ρ = 998,2 kg/m^3 and P_a = 101325 Pa, we obtain the maximum permissible annular velocity equal to W_* = 14 m/s. Annular velocity in the ROsá atomizers does not exceed the value of 12 m/s, and it reaches its maximum permissible value only at a pressure of 0.4 MPa. As a result of cavitation, an indentation area emerges in the top portion of the conical recess of the swirl chamber, but that does not affect either the flow rate or dispersion characteristics of the atomizer.

The ROsá centrifugal atomizer devised in Ukraine provides improved dispersity and ensures a durable, reliable and safe operation in sprayers.

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