SLOT SPRAYERS USED FOR WASHING AGRICULTURAL PRODUCTS

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Abstract

Agricultural products are washed in installations equipped with ball shower heads or zinc plated pipes with circular orifices or nozzles, in order to remove germs which are dangerous to consumers and to decrease the products’ microbiological charge. This paper presents the experimental results obtained with slot sprayers with a width/length ratio of the nozzle <0.25 for water pressures between 0.5-3.5 bar. The resulting water jet, characterized by its performance rating and spray coefficient, falls in the fine rain and fog group. The products can be washed with a continuous water sheet or a strong spray jet. Water consumption is lower than with ball shower heads with round orifices.

1. INTRODUCTION

Agricultural products and technological installations in the food industry are most frequently washed by being sprayed with water. Germs which are dangerous to consumers are thus eliminated, and the microbiological charge on products and installations is reduced. Equipment used for washing agricultural products has two or more groups of showers which wash the products that pass underneath. These showers have ball heads or they are made of zinc plated pipe provided with a number of nozzles which spray water onto the products to be washed or rinsed. They are operated at a pressure of 2 bars, which does not damage even the most sensitive products [1]. The nozzles have circular orifices, assimilated with unconnected orifices which operate under a steady load, spraying the water jet into the air [2]. The shower as a sanitary fitting for the washing installation ensures the filling of consumption points at the maximum admissible temperature and pressure required by the technological process.

The design of the washing devices must allow the easy maintenance of orifices or sprayers – cleaning, unclogging – the fast and easy replacement of the wear part, the filters or fittings with simple common tools, such as screwdrivers and simple or adjustable wrenches.

The standard design of the equipment takes functionality and safety into account, and the materials used are steel, brass, and plastic. Equipment for washing very sensitive agricultural products, e.g. leaves, can have a personalized design, with extra-fine or very fine drops whose diameter is between 1-100 microns.
2. RESULTS AND DISCUSSIONS

The manufacture of slot sprayers

Slot sprayers spray cold or hot water and transport the drops at a certain speed and pressure on the surface of the product or of the technological installation to be washed. As this is a complex subsystem, its design must take into account the following aspects:

- its purpose: washing agricultural products, leaves or sensitive fruit, separating rotten sections from healthy ones
- the size of the water drops: extra-fine drops of an average diameter of 1-35 microns; very fine drops of an average diameter of 50-125 microns; regular drops of an average diameter of 300-2,000 microns;
- the water can be sprayed through a slot with a section of a x b, in a stationary air stream, at a speed which varies with the pressure;
- the water under pressure comes through the calibrated slot of the sprayer and it is separated into fine drops which are transported through the air by their own kinetic energy;
- the device must be able to withstand the maximum admissible water pressure;
- the rugosity of the surfaces which come into contact with the water must be of 0.8-1.6 microns;
- it is recommended that a sediment filter be fitted before the slot, so that the latter does not become clogged with solid particles.

![Fig.1. Two slot sprayers: a. slot of 0.4 x 3 mm, b. slot 0.4 x 1.5 mm; 1 – nozzle, 2 –screwed muff, 3- O – ring, 4- filter, 5- pipe.](image)

Figure 1 shows two slot sprayers, one made of brass, with a rectangular slot a x b = 0.9 x 1.5 mm, and the other of plastic, with a rectangular slot a x b = 0.4 x 3 mm. They both have a sediment filter made of plastic in the sleeve (2) with the section of the orifice a x b = 0.7 x 0.7 mm, and a total of 49 orifices/cm².

Hydraulic and resistance calculations

The hydraulic and resistance calculations consist in determining the flow of liquid through the calibrated slot. The relation used is [2, 3]:

\[ q = \mu A \sqrt{2gp} \]  

(1)
where: \( q \) is the water flow through the slot, in \( \text{m}^3 / \text{s} \);
\( \mu \) - flow coefficient;
\( A \) - the slot section in \( \text{m}^2 \);
\( g = 9.81 \text{ m/s} \) - gravitational acceleration

The calculation flow of a compact water sheet, along the entire length of the washing device is determined with the expression

\[
q_c = n q
\]

where: \( q_c \) is the calculation flow of the washing equipment, in \( \text{m}^3 / \text{s} \);
\( n \) – the number of slot sprayers;
\( q \) – the nominal water flow through a sprayer, in \( \text{m}^3 / \text{s} \).

The resistance calculation determines the thickness \( s \) of the nozzle wall. The nozzle is considered a “tube with thin walls”. The thickness \( s \) results from the relation [4]:

\[
s = \frac{p_c \cdot D_i}{2(\sigma_a + p_c)}
\]

where: \( s \) is the wall thickness, in cm;
\( p_c \) – the calculation pressure, in \( \text{daN/cm}^2 \);
\( D_i \) - the inner diameter of the orifice, in cm;
\( \sigma_a \) – the admissible resistance of the material the nozzle is made of, in \( \text{daN/cm}^2 \);

3. EXPERIMENTAL RESEARCH

The two slot sprayers were tested on an experimental installation, fig. 2, and the following was determined:
- the dispersion angle \( \alpha \) of the water jet at different pressures;
- the variation of the water flow with the pressure;
- the intensity and fineness of the water jet;
- the uniformity of the water jet.

![Fig. 2. Experimental plant: 1 – water flow meter, 2 – tap, 3 – sediment filter, 4 – manometer, 5 – tank, 6 – pipe, 7 – slot sprayer.](image)

The liquid jet that comes out through the slot develops in the stagnant air and disperses under the action of gravitation, air resistance, and the inner forces of the liquid jet which cause turbulence in the jet. Two areas can be observed, depending on the pressure of the liquid: area 1 is compact, a water sheet whose length \( l \) decreases as the pressure rises; area 2, drop dispersion and formation, is a dispersion of liquid particles of different sizes in the air.

By increasing or decreasing the distance between the sprayer and the surface to be washed, the latter can be washed with the water sheet or the liquid particle jet (fig. 3).
The following conclusions can be drawn from the analysis of the experimental data obtained and the behavior of the liquid jet:

- as the water pressure increases, the length $l$ of the water sheet in area 1 decreases, as there is a reverse proportional relation between $l$ and $p$;
- as the water pressure increases, the diameter of the water drops decreases;
- the dispersion angle $\alpha$ of the water jet increases with the water pressure in the device, up to a maximum value;
- a dispersion angle $\alpha$ of approximately $100^\circ$ can be counted on at a water pressure of 2 bar;
- the fineness of the dispersed flow determined by calculating the performance rating with the relation [5]
  \[ K_f = \frac{L}{p} \quad (4) \]
  where $K_f$ is the performance rating:
  
  $L$ – the working length;
  
  $p$ – the working pressure, in m water column;
  
  can be included in the “very fine rain” group, as the $K_f$ coefficient is smaller than 1;

  the spray coefficient $K_p$, calculated with the expression [2, 5]
  \[ K_p = \frac{d_e}{p} \quad (5) \]
  where $K_p$ is the spray coefficient;
\[ d_e = 1.8 \ a [2] \] – the equivalent diameter of the rectangular section of the slot, in mm;

\( P \) – the working pressure, in m water column, places the water drops in the “fine rain” group, \( K_p \leq 0.25 \);

The jet sprayed in the free space of a length \( L=0.7 \) m in contact with the horizontal surface is elliptical in shape;

- the diameter of the water drops increases at the periphery of the jet.

4. CONCLUSIONS

Dangerous germs are removed and the microbiological charge on agricultural products is reduced by washing the latter in water jet devices. Due to their width/length ratio \((a/b < 0.25)\), slot sprayers have the following advantages, as compared to ball shower heads or showers made of zinc plated pipe with orifices or nozzles: a very good degree of uniformity \( >75\% \); the dimensions of the water jet are stable at a constant pressure; the entire quantity of water that flows through the slot is turned into small drops (fog); the water jet can be characterized according to its performance rating and spray coefficient as fine rain, \( a/b < 0.25 \); the device can be operated with both a continuous water sheet, and a strong spray jet; lower water consumption than with ball shower heads with round orifices.

BIBLIOGRAPHY