Pump and ejector design in wastewater treatment pilot equipment

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Introduction

Generally, wastewater treatment plant is composed of three parts: primary (physical), secondary (biological) and tertiary (refinement) operations. Specifically, tertiary treatments are carried out to reach a specific water quality following downstream treatments. In the case of textile industry, refining treatments are often required to adequately remove residual colour, surfactants and salts, to reach quality specifications for process water recycling.

Ozone treatment is an oxidative process, specific to demolish the chromophoric bonds or groups in the dye molecules: it generates a high efficiency de-coloration [1].

A method for intensifying the ozone transfer into water and maximize ozone-water mixing is provided by Venturi ejectors.

Venturi ejectors consists of a short tapered pipe section which ends in a throat and then a second conical section is designed with a smaller angle (Figure 1). Recommended proportion to minimize the net pressure drop are inlet angle α_1= 21° ± 2° and outlet one α_2= 5° to 15° [2].

Forcing water through a Venturi system a moderate pressure drop between the inlet and the outlet, and, according to Bernoulli principle, generate a minimum pressure in the throat section, thus having the possibility to suck in another fluid, either liquid or gas, the oxygen/ozone mixture in this specific case.

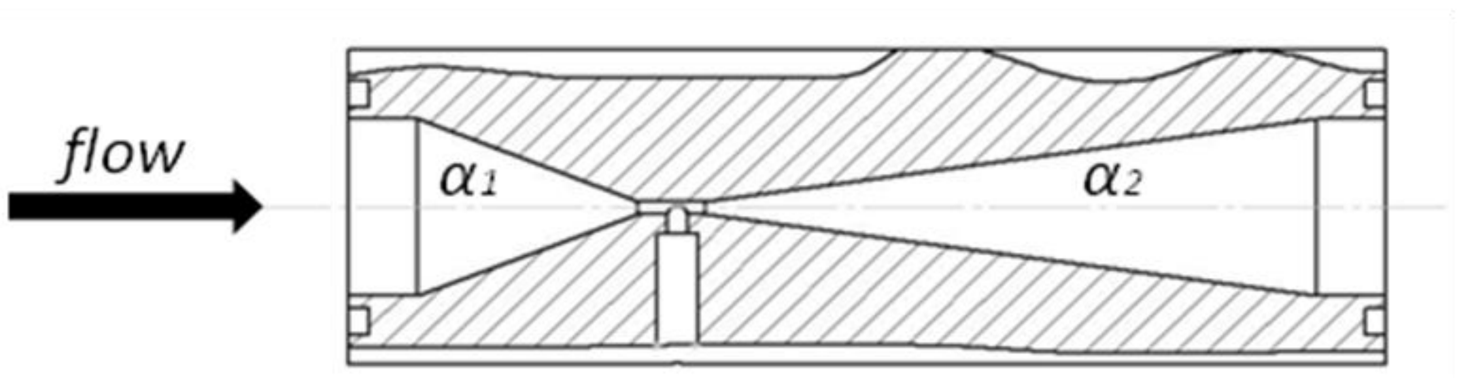

Figure 1. Venturi ejector scheme

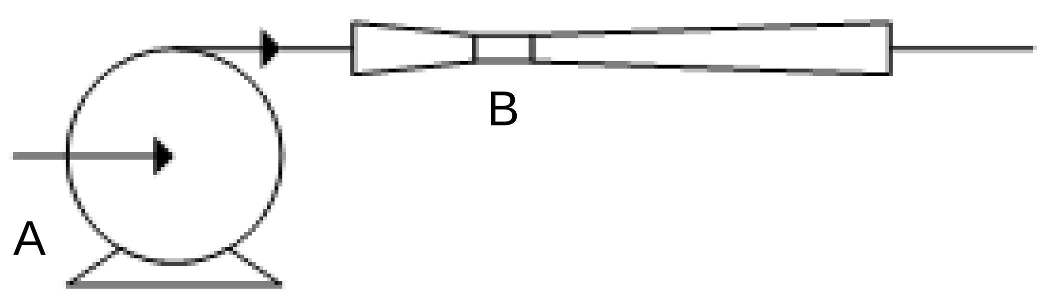

Figure 2. Schematic plan representation: A - pump, B - Venturi ejector

Computational Methods

A 2D axisymmetric model has been used in order to determine the characteristic curve of the ejector (pressure drops) and the generation of a low pressure in the throat section. The *k-ε* turbulent flow model was set in COMSOL; this allows to use Navier-Stokes equations for conservation of momentum and the continuity equation for conservation of mass. Turbulence effects are modelled using the standard two-equation *k-ε* model with realizability constraints. Flow close to walls was modelled using wall functions. The liquid (water) was considered incompressible.

As boundary conditions, the inlet velocity was set in a range of 0.036 to 1.296 m/s (in term of volume flow rate in a range from 0.13 to 2.7 m^3/h) and the outlet was set to atmospheric pressure.

The characteristic curve of the system is fundamentally given by the ejector. The ejector diameter and outlet angle α_2 were changed to define the characteristic curves (α_1 = 21°).

To compare experimental and simulated data, equivalent sand roughness height was imposed to the model.

Results

The results of the simulation provide the ejector characteristic curves as a function of geometric parameters and the evaluation of the pressure value in the ejector throat. Moreover, the equivalent sand roughness height is defined comparing experimental and simulated data.

In Figure 3 three pump characteristic curves corresponding to Lowara 3 SV pump with 4, 6 and 8 stages are reported. The desired working conditions (outlet pump pressure and flow rate) are been defined by intersecting the ejector and pump characteristic curves.

Ejector parameters (diameter and α_2) and pump type are chosen comparing their characteristic curves.

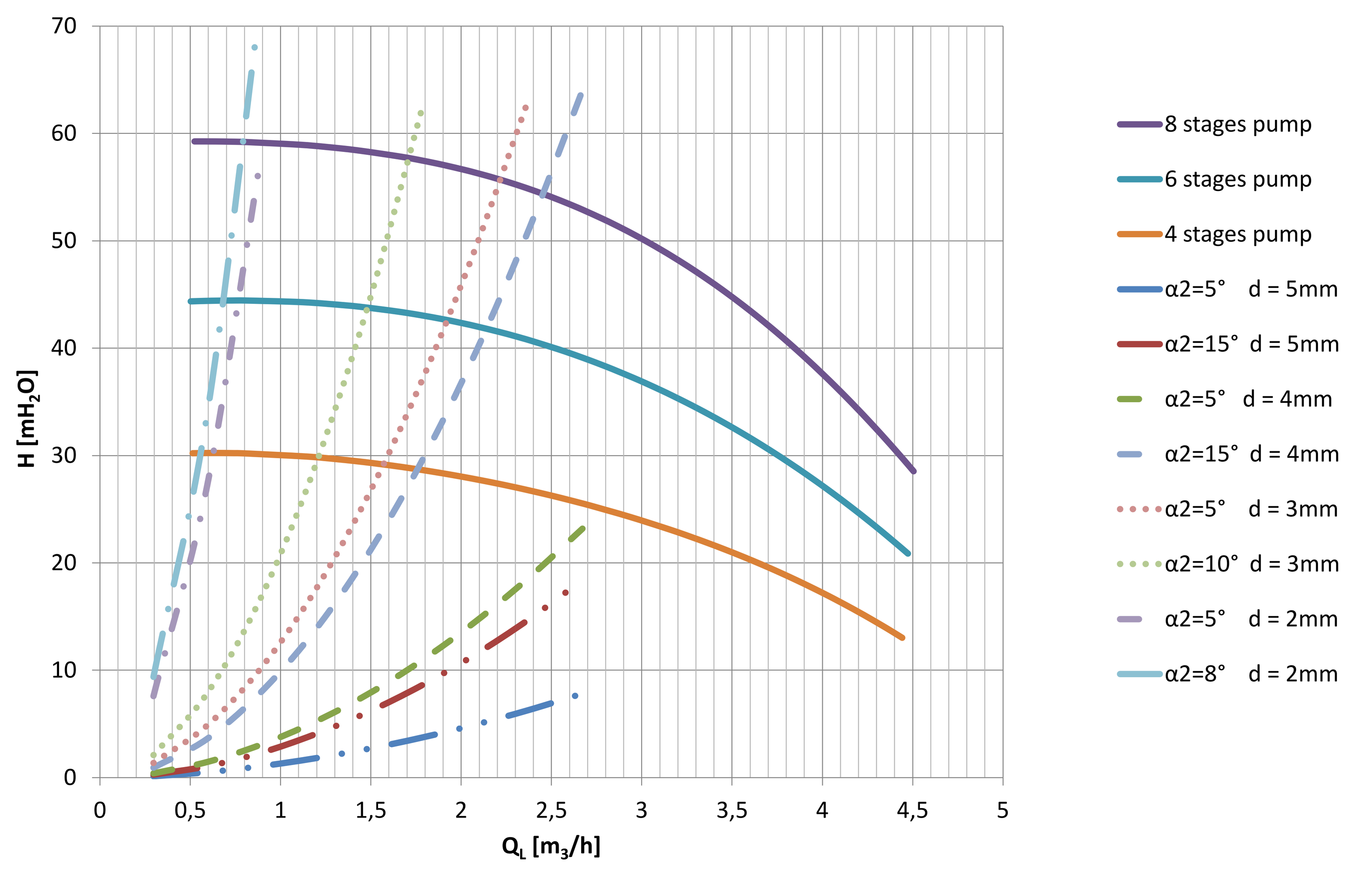

Figure 3. Pump and ejector characteristic curves

The best performing ejector has the following characteristics: 2 mm diameter and α_2= 8° . Equivalent sand roughness height is equal to 0.2 mm which correspond to an actual roughness of about 32 µm. The 8 stage pump is the best to the chosen ejector for the working conditions of the case.

The vacuum in ejector profile was given by all the simulations. Figure 4 shows the relative pressure profile as a function of the axial coordinate. The measured pressure in the narrow section is 0.8 mH_2O.

In the following graph (Figure 5) the Venturi ejector characteristic curve without roughness and with equivalent sand roughness of the tested ejector are compared.

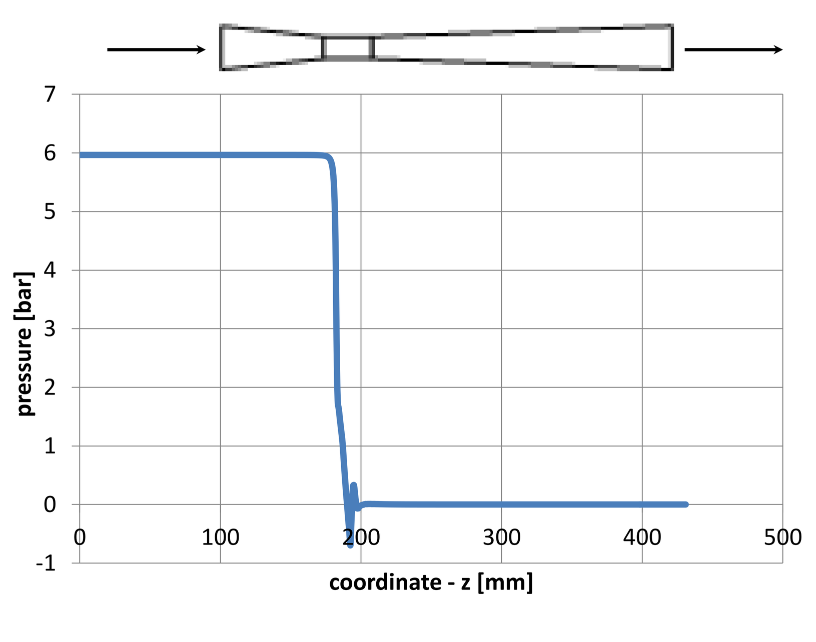

Figure 4. Pressure trend along the ejector

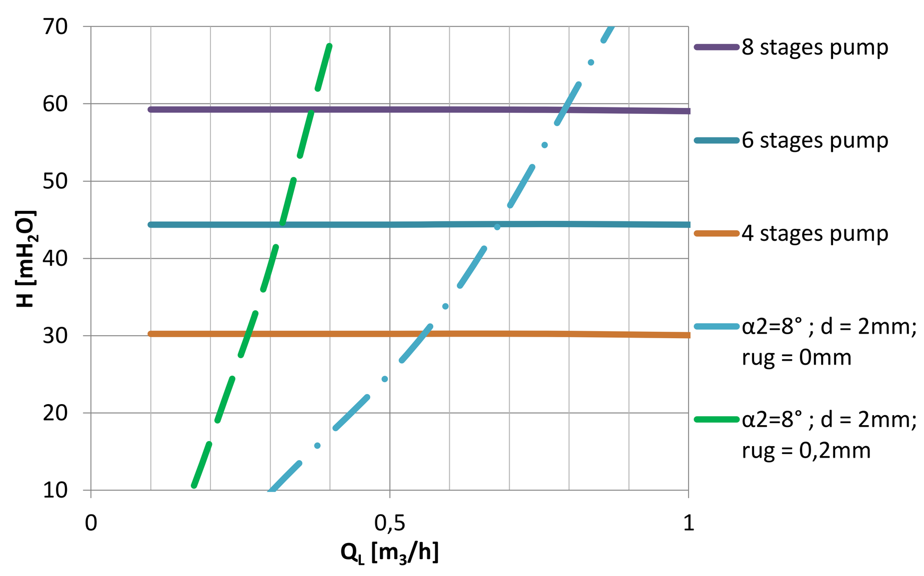

Figure 5. Characteristic curve with (--)/ without (-·-) equivalent sand roughness

Conclusions

The study was demonstrated useful to define the design parameter of the ejector. The working conditions (pump outlet pressure and flow rate) given by the simulation based on equivalent sand roughness were validated in the pilot equipment.

References

[1] K. Turhan, Z. Turgut, Decolorization of Direct Dye in Textile Wastewater by Ozonization in a Semi-batch Bubble Column Reactor, Desalination, 242(1), 256-263 (2009)

[2] R. Perry, D. Green, Perry's Chemical Engineers' Handbook, 5th edn., 5-12 to 5-13 (1973)

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