STUDY AND OPTIMISATION OF A CO$_2$ SPARGER FOR CARBONATED BEVERAGES AND BEER BY MEANS OF CFD MODELLING

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ABSTRACT

In the present work, two different geometries of spargers for beverage carbonation were modelled by means of CFD technique. The first geometry presented a radial inlet of liquid food while the second one a tangential one. Calculation allowed to identify the best solution and mathematical results were confirmed by experimental tests with both water and apple juice. CFD resulted a very useful technique for in-silico designing not only for simple parts of plants but also for very complicated ones such as carbon dioxide spargers in which gas and liquid ix together.

Keywords: carbonated beverage, computational fluid dynamic, dense phase carbon dioxide,

1. INTRODUCTION

The consumption of soft drinks in their various forms has taken place for many centuries in order to meet the body's fundamental requirement for hydration. The discovery of the means of artificially carbonating water by dissolution of CO2 under pressure is attributed to Dr Joseph Priestley in the late 1760s, though there were many other workers active in this field at the same time which probably deserve equal credit.

Production of carbonated drinks was traditionally carried out by means of adding concentrated syrup to the bottle and then topping up with carbonated water. A considerable improvement in speed was achieved in 1937, when the Mojonnier Brothers Corporation of Chicago introduced a continuous blending/cooling/carbonating system (Steen and Ashurst, 2008).

In general, two basic methods for carbonating a drink are possible: the injection and dispersion of carbon dioxide into the liquid to be carbonated, and the fine spraying of the product into a carbon dioxide atmosphere. However, in-line carbonation methods are being used increasingly. These either sparge carbon dioxide into the liquid or inject the liquid into a gas stream. When the gas is sparged into the liquid this allows small bubbles of gas to be formed which can be easily absorbed by the liquid. The higher the pressure the smaller the gas bubbles formed at the sparger and the greater the gas bubbles surface area available for the gas to be absorbed by the liquid. In addition, also design of both the spargers and the housing of the sparger play an important role in optimal dissolution of gas into liquid. For this reason the aim of this work was to study and optimize different designs of CO2 sparger for water or soft drink carbonation by means of CFD modelling.

2. MATERIALS AND METHODS

Two sparger geometries were studied and modelled by means of computational fluid dynamics technique.

The modelled sparger geometries were firstly drawn by means of SolidWorks 2013 and then 3D simulated by means of ANSYS 14 software with Boussinesq's approximation that uses a constant density for both fluids but considers gravity acceleration as a function of expansiveness and temperature of fluids. Sparger for carbonation presented a diameter of 64 mm and an height of 203 mm. the two geometries are reported in figure 1.

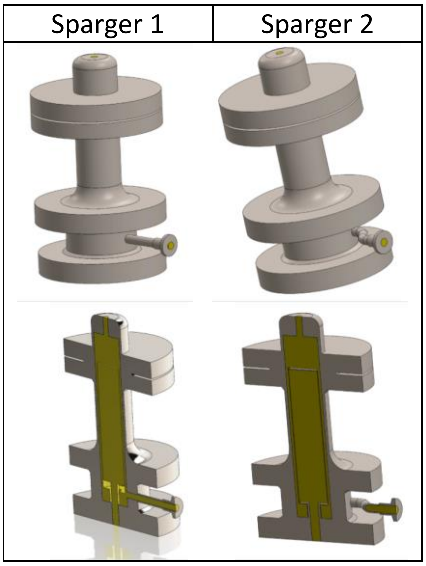

Figure 1: Radial (Sparger 1) and tangential (Sparger 2) sparger geometries

Flow rate of the food liquid was set at 16 L/h while carbon dioxide at 5.6 L/h. The incoming fluid was considered water while carbon dioxide was considered as the gas. Properties of fluids are reported in the following Table 1:

Table 1: Properties of modelled fluids

	CO_2	Water
Molar mass [$kgmol^{-1}$]	44.01	18.02
Density [kgm^{-3}]	1.977	997
Dynamic viscosity [$mWm^{-1}K^{-1}$]	0. 0149	0.8899
Thermal expansivity [K^{-1}]	0.00366	0.000257

After modelling, water carbonation was experimentally tested on a pilot plant developed by Valfor srl and located in University of Parma laboratories. The pilot plant presented a total volume of about 2 L and a flow rate varying from 10 to 40 L/h. The equipment could work up to 200 bar and presented several water baths to have constant temperature both of carbon dioxide and product to be carbonated.

The carbonation evaluation was performed by means of image analysis: on the pipeline of the pilot three inspection units as reported in Figure 2 made of transparent polycarbonate were added. By means of a camera images of carbonated water were obtained and dimensions of gas bubbles were measured.

Figure 2: Inspection unit for bubble measurement

3. RESULTS AND DISCUSSIONS

As shown in Figure 3, tangential connection (Sparger 2) seemed to give a better mixing of gas and liquid at the

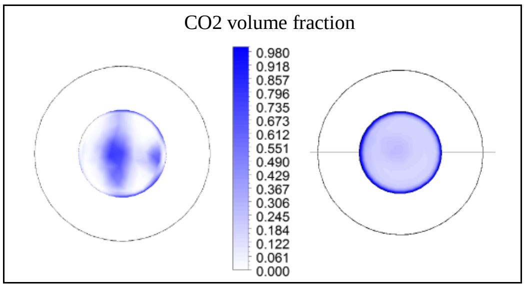

Figure 3: CO2 volume fraction distribution in the outlet section

On the contrary, in Sparger 1, fluid streamlines were present with less homogenous dispersion at the outlet of the sparger.

In Figure 4, sections of both spargers are reported: as previously observed Sparger 1 presented streamlines with a less homogeneous mixing efficacy.

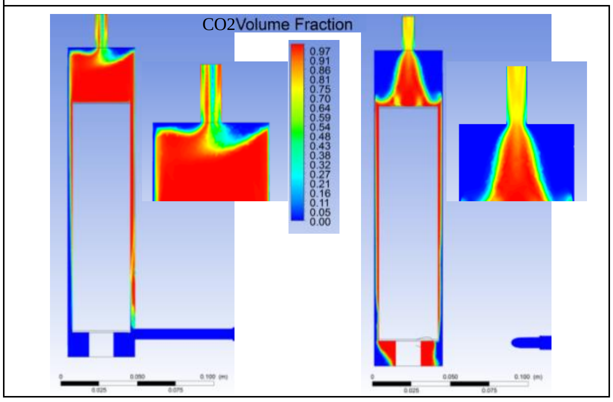

Figure 4: Radial (Sparger 1) and tangential (Sparger 2) sparger geometries results of modelling

As it’s possible to see the housing for the sparger was the same while the angle of the inlet flux changed. The gas entered from the basis in the central channel and the liquid food from the lateral connection. Thus, mixing results depended only on fluid flow and relative movements between liquid and CO2

In order to quantify mixing efficacy, CO2 volume on the radius of the outlet of the sparger was calculated and reported in Figure 5

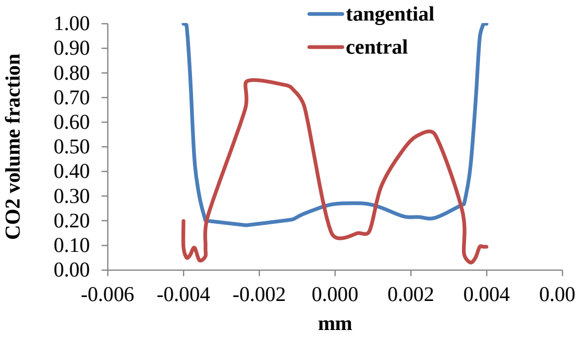

Figure 5: CO2 volume fraction distribution in the outlet section

Data confirmed what previously observed: Sparger 2 gave a more homogenous distribution but unfortunately gave also a lower mean CO2 volume fraction with a worse mixing effect. In Sparger 2 a great part of gas exited near the wall of the pipe without an actual dissolution into the liquid.

Picture of inspection element (Figure 6) confirmed the presence of gas bubble near the wall in Sparger 2 that were not mixed with liquid

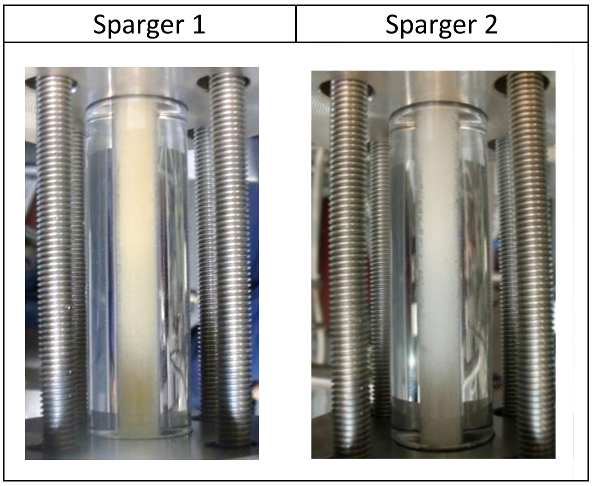

Figure 6: Bubbles inside the inspection unit

Also from experimental tests Sparger 1 gave better results with a better mixing between water and CO_2 and a more stable carbonated water, as consequence. Thus tangential inlet was not the best solution even if the liquid generated itself turbulence inside the housing and prevented fluid streamlines formation. Probably, turbulence inside the Sparger 2 and the spiral flux on the filter limited the spilling of CO2.

4. CONCLUSIONS

In conclusion, this work demonstrated the effectiveness of mathematical model to predict fluid mixing also in complex systems and the usefulness of these models for designing and optimizing also gas sparging systems for the beverage industry.

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