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Development of an optical fiber sensor for monitoring the flow of colloidal nanoparticles

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Abstract

An optical fiber sensor for monitoring dynamic systems of colloidal suspensions is reported. The system is comprised of a reflection-type quasi-elastic light scattering fiber probe that is placed on the assessed flow. The measurements were conducted for colloidal silica subjected to laminar flow condition, yielding 0.117 s/cm velocity sensitivity for 2.0 wt%. Furthermore, the decay rate of the scattered light intensity was correlated to the sample characteristics by artificial neural networks, providing 0.09 wt% and 0.3 cm/s errors concentration and velocity measurements, respectively.

Key words: *Colloidal silica; optical fiber sensor; artificial neural networks*

Introduction

The assessment of colloids subjected to flow conditions is essential for biochemical, biomedical and food applications [1]. However, the currently available instruments for such tasks are invasive and expensive, so the fiber optic quasi-elastic light scattering (FOQELS) sensor figures as a feasible alternative for such applications.

The sample concentration C can be estimated by the decay rate Γ of the autocorrelation function [2]

$$G_2(\tau) = A + B\exp(-2\Gamma\tau), \qquad (1)$$

where A and B are constants and τ is the delay time.

Albeit the FOQELS was previously validated for measuring the concentration of colloidal silica [3], in flow conditions the advection is superposed to the diffusion as given by the Péclet Number (Pe),

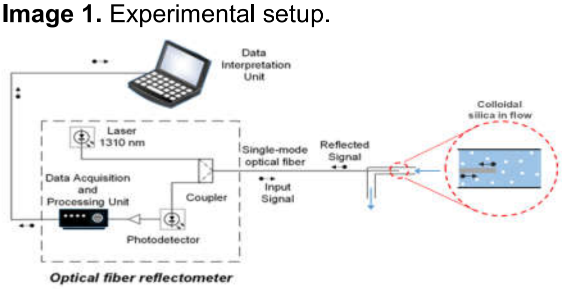
$$Pe = VL/D_0, \qquad (2)$$

where V is the velocity, L is the tube diameter, and D_0 is the diffusion coefficient of the particles. Consequently, by measuring Γ it is possible to estimate C and V.

Results and Discussion

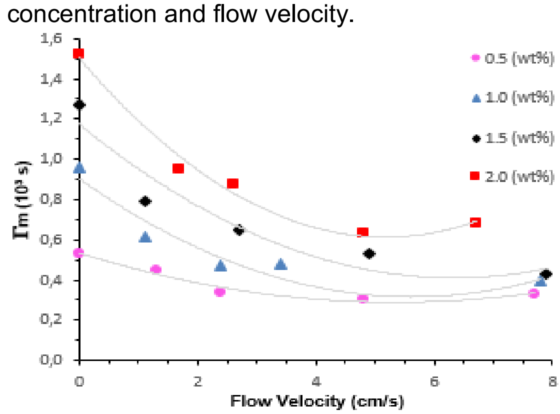
Silica nanoparticles (~189 nm diameter) were dispersed in deionized water to produce suspensions with concentrations from 0 to 2.0 wt%. Next, measurements under flow conditions (up to ~8 cm/s) were carried out by inserting the fiber probe parallel to the streamline in a 6 mm diameter silicone tube, whereas the reflected intensity signal was acquired with 1 kHz sampling rate, as shown in Image 1.

Image 1. Experimental setup.



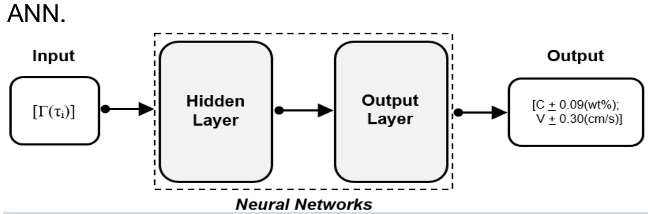
According to Image 2, Γ increases with C, but decreases with V, corroborating the theoretical model. The sensitivities for velocity measurements are 0.117 and 0.025 s/cm for samples of 2.0 and 0.5 wt%, respectively.

Image 2. Average decay rate as a function of the sample concentration and flow velocity.



In order to simultaneously evaluate C and V, the Γ value was calculated for delay times τ_i ranging from 100 to 1000 ms, and the $[\Gamma(\tau_i)]$ arrays were correlated to the output variables by an artificial neural network (ANN), Image 3. The system was tested with 10-fold cross-validation [4], providing average errors of 0.09 wt% and 0.3 cm/s for concentration and velocity, respectively, which is comparable to other techniques [1].

Image 3. Determination of concentration and velocity by ANN.



Conclusions

The optical fiber sensor was successfully validated on the simultaneous measurement of the concentration and velocity of colloids under flow conditions. Further developments will concern the integration of this system to microfluidics for practical application in biochemical applications.

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[1] Leung, A. B., Suh, K. I. and Ansari, R. R. Appl. Opt. **2006**, 45 2186
[2] Finsy, R. Adv. Colloid. Interface Sci. **1994,** 52 79.
[3] Soares, M. C. P.; *et al.*. **2019,** Braz. J. Chem Eng. 36.
[4] Kohavi, R. IJCAI **1995.**