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Particle characterization by analyzing light scattering signals with a machine learning approach

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We present here a new instrument, to our knowledge, in combination with a machine learning approach to achieve a more cost-effective and compact measurement instrument for particle characterization in a flow based on the established measurement technique known as the time-shift-time-of-flight (TSTOF) technique. A commercial device based on TSTOF was introduced and has since been recognized under the brand name SpraySpy. In this study, we propose a machine learning model capable of using only a single signal in this device to determine the same information about particles, such as particle size and particle velocity, traditionally obtained from the classical measurement device based on the TSTOF technique, where four signals have been used. To achieve this, we train a machine learning model using the four signals, but connect only a single signal to the model in the final step. The initial experimental results have been conducted, and preliminary calculations demonstrate high potential for this method. By applying this method, one light source and three detectors, along with the corresponding electronics and optics, can be eliminated from a TSTOF measurement instrument. This not only reduces hardware costs but also enables the production of a smaller measurement probe and the use of a single signal acquisition system without the need for synchronization.

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1. INTRODUCTION

The time-shift-time-of-flight (TSTOF) technique is a measurement technique for particle characterization, mainly serving as an extension and modification of the well-known time-shift measurement method [1]. The time-shift technique was first introduced by Semidetnov [2] in his 1985 dissertation, with further developments made by Pavlovskii [3] in 1991, and by Albrecht [4] and Damaschke [5,6] in 2002. The TSTOF technique was initially proposed by Schaefer [1,7] in his 2012 dissertation, where a commercial instrument that combines the time-shift (TS) and time-of-flight (TOF) techniques was presented [8].

Since its inception in 2012, the TSTOF technique has undergone significant development, leading to the publications of several concepts also in the characterization of complex or emulsion/suspension particles [9–14]. The most recent and comprehensive description of this measurement method is available in [15,16]. In [15], the TSTOF has been modified so that the measurement of particle size (d) and velocity (v) is achieved by analyzing the time intervals and the time-correlated light scattering signals. In [16], the TSTOF technique was combined with a polarization modulation of the light beams, so that an oscillating signal bounded by two signals was created to achieve more information depth and practical advantages in signal analyses.

In this work, we present a new modification of the TSTOF technique, where the classical measurement device based on the TSTOF technique will be reduced in such a way that, instead of four signals, only one signal will be used. We propose using a machine learning approach to analyze a single signal for particle characterization, which is traditionally obtained from the classical measurement device based on the TSTOF technique, where four signals have been used. The reduction in the number of signals leads to a reduction in the components of the instrument, which leads to a more cost-effective and compact measurement instrument. The machine learning model will be trained using the four signals, but will be connected in the final step to only a single signal to the model. The initial experimental results have been conducted, and preliminary calculations demonstrate high potential for this method.

The modification of the TSTOF measurement instrument presented in this study leads to a significant reduction