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Development of a new temperature measuring system for gas–liquid flow in spraying field

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Abstract

Based on previous work, a new temperature measuring system for gas–liquid flow, composed of shielded and unshielded thermocouples, on-line laser detection device for liquid droplets, vacuum pump and wavelet analysis data processor, is developed in this work. The necessity of vacuum pump and the criterion of mesh size selection are also described. Through an application of measuring temperature in saturator, it shows that the system can evaluate the separation of gas–liquid two-phase flow and measure the liquid droplet temperature and the gas temperature effectively in counter-current spraying field.

Keywords: Gas–liquid two-phase flow; Spraying; Flow separation; Laser scattering methods; Image analysis; Wavelet analysis

1. Introduction

The liquid to gas spraying technology is now widely used in chemical industry [1,2]. The liquid from a nozzle is split to small size droplets and diffused into gas flow. With the wide applications, the research interest in liquid to gas spraying flow has been aroused considerably. A lot of numerical analysis methods, based on mathematic model as well as the relative measuring technology, have been developed very quickly [3].

At present, non-contact optical methods are often applied in the measurement of spraying field, namely phase Doppler anemometry (PDA) [4–6] and Malvern instrument [7,8] for liquid droplet size and velocity; particle image velocimetry (PIV) for the whole flow field pattern [9–11]; high-speed camera for droplet velocity, atomization angle and distance [12]. X-ray optical method has been developed for measuring the mass of liquid phase [13]. Using the methods mentioned above, we can obtain many characteristics of gas–liquid spraying field. However, the measurement of two-phase flow temperature, which is very important in determination of mass and heat transfer between two phases, is still with some difficulties.

The laser holography and laser induced fluorescence (LIF) methods are utilized to measure the temperature of liquid droplets in gas–liquid spraying flow [14,15]. Provided the relationship between the temperature and radiant intensity, monochromatic absorptivity, monochromatic emissivity or other parameters is given, liquid droplet temperature can be calculated indirectly. But this relationship, strongly depending on the properties of fluids and test conditions, is difficult to establish. More measurement difficulties will occur during the process of varying temperature. Furthermore, the methods described above only measure the temperature of liquid phase but fail to obtain gas phase temperature. An instrument with thin-film thermocouples is used to determine air temperature and oil droplet temperature in the diesel engine [16]. According to the different responsive time of thermocouples, the data processing technology is utilized to identify temperature signals of two-phase flow. But this instrument did not take

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effective steps to assure the perfect separation of air flow and oil droplet, the results are not convincing.

Wang designed an experimental device, which is composed of a shield, copper mesh and thermocouples for measuring both liquid droplet temperature and gas temperature independently [17,18]. The thermocouples outside the shield are used for measuring temperature of liquid droplet and the thermocouples inside the shield are utilized for measuring gas temperature, since the copper mesh can prevent most of droplets from entering the shield. A lot of test results show that Wang's device can get the temperature difference of two-phase flow in spray tower. This is large improvement in measurement technology in spraying field. However there are still two questions which we have to raise: (1) Is the gas phase well separated from the two-phase flow? (2) How to select the proper mesh number at different operating conditions and what is the criterion of selection?

For this purpose, based on Wang's device, a new temperature measuring system has been constructed. Compared with conventional gas–liquid separating device, this system has many advantages: it can judge the separation effectiveness, which has a crucial influence on the measurement accuracy of two-phase flow; the selection of proper mesh number can be determined by signal fluctuation; on-line temperature is measured and the abnormal results can be detected and eliminated with wavelet analysis technology, etc.

2. Original experimental facilities

The measuring tests of gas–liquid two-phase temperature were carried out in a counter-flow spraying tower with high relative humidity condition [17]. Fig. 1 shows the scheme of the experimental facilities which consists of an adjustable frequency blower, the saturator, a pressure-swirl atomization nozzle, a water tank for supplying and heating water and the air adjusting box for changing the humidity and temperature of inlet air flow. The height of the saturator is 2 m and the section area is rectangle with 0.3 m multiplying 0.3 m. Other detailed information of experimental facilities is described in Ref. [17].

Fig. 2 shows the structure of the device developed by Wang for gas–liquid temperature measurement. It is composed of a shield of engineering thermal-isolated plastic,

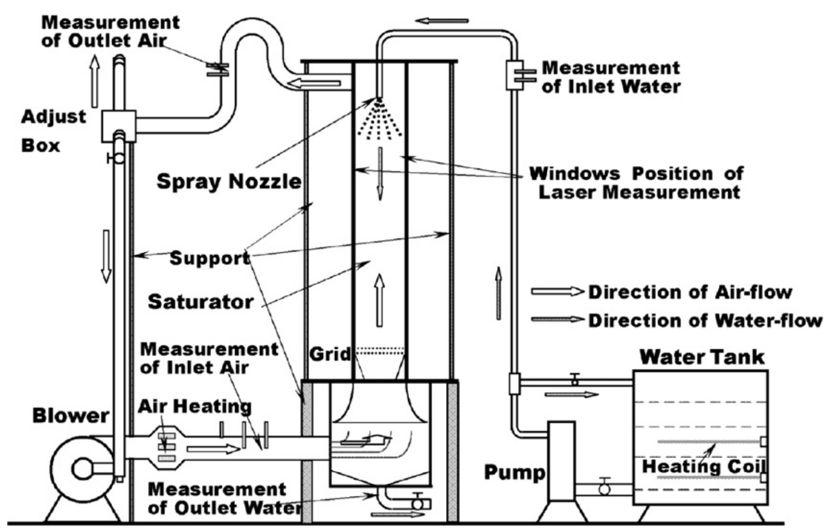

Fig. 1. Sketch of experimental facilities.

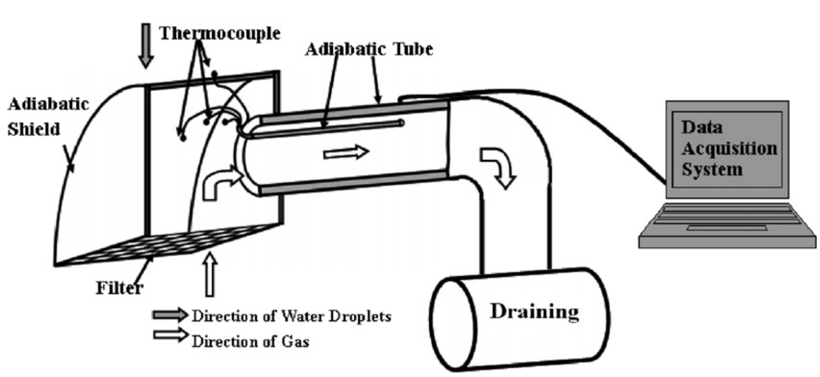

Fig. 2. Original device for measuring temperature of gas–liquid two-phase spraying flow.