An Erosion Harmful Droplets Mean Size Measurement Method Using Contactless Method in Polydisperse Wet Steam Flowing

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**Abstract:** The study described here is a novel way to precisely estimate the mean diameters of droplets in wet steam flow; it blends methods from experiments with computer simulations. This method's main component is the use of laser diagnostic equipment to gather comprehensive data. The paper explores basic issues that are important to use this method, specifically concentrating on how to use it in static settings in an innovative steaming dynamical system. The main findings of this study demonstrate the method's good verification and demonstrate how well it can be used to analyse the motion of moist steam flow, particularly in a setup with decreasing flat nozzles.

**Keywords:** Wet steam; Erosion; Heat transfer; Nozzle; Steam dynamic; Steam flow

# Introduction

One attractive area of growth for the Russian turbine manufacturing sector at the moment is the creation of low-pressure chambers (LPCs) for steam-powered turbines with greater output capacities. The effectiveness and dependability of the blade system's function in wet steam circulation circumstances are subject to strict criteria, as among the most significant design components of the generator's flow route is the girth of the last blade. The existence of the liquid state has a major impact on the operational circumstances of turbines that generate steam at nuclear power stations (NPPs) and LPC, the final blade of turbo engines at thermal energy facilities (TPPs) [1]. There are two types of moisture present in the fluid's path: a film of water on the exteriors of the interclade canals and a polydisperse droplet movement. Aside from additional electrical loss brought on by thermodynamics and mechanical forces among the two phases, abrasion degradation of rotor blade edges constitutes one of the detrimental impacts of the solution state. The procedure, whose magnitude mostly relies on the running blade's circumference acceleration, establishes a maximum percentage of humidity in the turbine's final steps [2].

Currently, techniques for reducing eroded wear involve injecting steam close to the exterior walls of guiding feather interblade passages and removing moisture from the outermost layers of rotor equipment circulation path elements. The primary goal of these actions is to eliminate moisture film, which acts as a source of dangerously distributed water that causes eroding [3]. While maintaining a high cost-effectiveness of stage operations overall, designers designing water separation and warming injection with steam systems should consider the aerodynamic disturbances they induce in the flow. The primary indicator of how effective these interventions are is how much the concentrations and size of the big drops upstream of the vane that guides the cascades are reduced. Information on these variables' values is crucial for testing the elimination of moisture and warming injection with steam systems at static settings, as well as while operating steam turbines on modelling rotors [4]. The discovery of new techniques for estimating average droplet sizes in a polydisperse damp steam stream is made possible by the advancements made in contemporary experimental approaches used to investigate flows. These techniques can be effectively utilised at every stage of experiments aimed at introducing effective techniques for controlling erosion-hazardous water. This paper describes and provides the first findings from the validation of a hybrid experimental and computational method for estimating the mean particle dimensions, which is based on the application of a laser-based flow diagnostics device.

# Experimentations

## Operating principle

Currently, the movement of coarser distributed water in the turbine equipment flow route element is studied using a Lagrangian technique. This method models the movement of every single droplet, making it feasible to figure out the paths and primary velocity (acceleration, speed, and trajectory perspective) of separate stage fragments together according to the first stated water spread structure at the channel's intake. It is important to note that certain procedures related to transition and intraphase interaction—such as droplet division and the coagulant and the removal of water film from areas before the development of big droplets—are difficult to model and lack a general computational explanation. Consequently, the movement of particle streams within the interaxial spaces of the final stages of the steam turbine can't be fully understood by a researcher. Nevertheless, an investigator may resolve the opposite issue of estimating droplet sizes by starting with a trend in which the constant media speeds or slows the droplets and using empirically obtained fields for fluid speeds and the primary flow variables. Additionally, as variations in the aqueous size of particles impact droplet inertia and, therefore, droplet motion characteristics, one may make judgements on the complex mechanisms of particle disintegration and clotting based on information regarding droplet speeds. The crossing correlation nanoparticle imaging velocimetry (PIV) approach embedded within the laser flow diagnostics equipment allows the determination of the immediate velocity domains of laser lit indicators embodied in single fluid particles. To acquire typical findings from the field study, information on momentary vector areas of speeds is processed statistically. The optical diagnostics equipment has been altered to allow for the potential investigation of polydisperse stream movement [5].

The following piece presents a method for analysing the movement of finely distributed droplet streams on their distinctive paths, based upon the Lagrangian method. The method works on an average fluid-phase speed field. As opposed to the earlier frictionless approaches, which were characterised by determining the mean size of droplets at a spot, this methodology allows one to measure the average drop size throughout a specific area. It is noteworthy that the current capabilities of the technique under consideration are restricted to averaging the sizes of droplets across concentrations; the user cannot acquire a droplet's densities or dispersion functions. The technique created may be used in the future to verify the distributed composition of both the miniature and completely steam engine LPCs.

# Result and discussion

The new method was tested at the tip of the nozzle at various stream-type parameters. The smallest part of the channel's geometry preserved the flow's vital parameters in every mode (i.e., the resonance speed had been reached at the nozzle's output). This prevented oscillations at low frequencies of the fluid's flow rate characteristics from occurring. Variations were also made to the liquid-to-vapour phase proportion and the initial moisture level in vapour (y0). The patterns of droplet median diameters (through concentrations) throughout the nozzle, as determined using an elastic particle deposition sensor and the devised approach, are shown in the eighth figure. The information that is shown shows that the computed data and the measurement findings correspond rather well [8-14]. On the KVP2 exploratory rig situated in the Turbine Equipment Issues at the Russia Power Engineers Institute Studies University, the head of It and Petroleum Generators, a combined exploratory and computational method for estimating the typical size of droplets had been refined. This gear permits the movement of overheated, flooded, and moist steam flowing in rotor gear flow pathway components to be explored in a broad range of operational conditions [6, 15-23].

The fundamental circuit and exterior look of the rigs are depicted in Fig. 1. The feed water is added in two phases to bring the heated steam off the turbine exhaust to a saturated condition. In the rig reception reservoir, dry steam that is saturated is created as a neutral medium. A set of steaming blasting nozzles is used ahead of the item of machinery under study to produce the initial amount of moisture in the operating fluid. These nozzles pump water from the feed system into the receiving tank to establish a polydisperse liquid state. Figure 1 displays how they function densities (by weight and concentrations) in relation to the size of the produced droplets. The investigated channel receives the previously prepared moist steam medium, which is then sent to a condenser. The condensation that is produced is then fed back into the electrical plant's heat cycles [7, 24-30]. A more narrowed symmetric orifice was chosen as the apparatus to validate the suggested approach; its geometric properties are displayed in Fig. 1. An accelerometer droplet deposition probe was used to confirm the findings, and it was placed into the flow via holes 1-6 in the channel's medial side. The fluid substance-applied catching surfaces were set transverse to the line of circulation. Following the preservation of the beads Report Word that had fallen on the instrument's surface, the instrument was removed from the passageway, and a magnifying glass was used to take pictures of the precipitate liquid-like nanoparticles. The dispersed structure of the gaseous phases at all of the waterway sites under consideration was determined using the acquired number of photos [31-37]. As previously mentioned, the new approach is implemented using data on the liquid phase speed areas, which may be gathered using a laser diagnostics device. Fig. 1 illustrates the installation's fundamental circuit for using it in a channel. The mirror directs the dual-impulse lasers’ beam blades towards the object under study via an optic glass set inside the channel top insertion [8]. A fast-speed lens may capture images of the droplets flowing in the centre region of the nozzle because the illumination plane created in this way highlights them. The PIV approach uses the produced particle stream pictures as beginning data. In this work, we examined isolated midrange velocity fluctuations in the drainage region where perforations are positioned for inertia rainfall probe verification observations [9, 38-45].



**Figure 1.** The droplet distribution by size functional intensity



**Figure 2.** Comparison of typical droplet dimensions for various starting steam parameters along the nozzle

Upstream of the waterfall, each of those step’s results in an increase in the profile loss of vapour energy from motion. It is crucial to stress that the geometry of the turbine flow channel and flow mode variables play a major role in determining how these procedures impact the primary flow properties. These methods have a significant impact on steam phase variables upstream of the vane cascade when conducted in static testing of detached avenues (it was precisely in those circumstances that the thought about the process was clarified). These experiments are conducted at low degrees of turbulent flow and using a dominant amount of roughly scattered water that is deliberately produced by using nozzles. We employed the usual k-ε turbulence model to compute a completely turbulent fluid flow, which resulted in an inflated amount of electrical loss in the boundary layer of the system. This allowed them to be partly included in the computation results [10, 46-53]. They were capable of properly simulating the existence of films on the channel surface and motion-related activities via this approximation method. After being adjusted in line, the swirling model put into use proved appropriate for estimating moist steam flows. Furthermore, the International Consortium for the Characteristics of Liquid and Vapour offered its dependencies on the basis of the thermodynamic characteristics of steam and water that were integrated into the moist steam models used in the Ansys Fluid CFD system [11]. The purpose of doing this was to compute several flow mode characteristics more precisely and compare the outcomes with the findings from the experimental observations. An extra vector field postprocessing technique based on work was used to reduce adverse impacts [12]. Because the created approach replaced "falling out" vectors and restored "lost" ones, it also improved the overall smoothness of the collected data and reduced empirical sound, allowing us to get more comprehensive data on speed fields. This approach's foundation, a wet steam mathematical framework, makes it possible to compute flow parameters while accounting for nonequilibrium phenomena [13]. The study makes the assumption that the liquid particles are tiny in size and follow the current lines of the main flow without sliding. Therefore, the numerical simulation outcomes only consider the thermodynamic aspects of the phase-to-phase interactions and neglect to account for processes that grow more intense in the presence of finely scattered wetness in the stream [14]. These procedures might significantly impact the primary flow energy and, in turn, velocity parameters. The accuracy of lighted droplet photos is negatively impacted by all of these parameters, and as a consequence, there are significant mistakes in these velocity vector field computations. As a prime instance, a liquid phase vector field derived using the PIV approach upstream of the plate's departure border is shown in Fig. 2. This graphic makes it easy to spot "falling-out" directions and areas where the method was unable to compute acceleration matrices [15].

# Conclusion

In summary, the use of laser diagnostic instruments in conjunction with a combined computational and experimental strategy has proven to be a useful and efficient method for estimating the mean sizes of particles in humid steam fluxes. Promising findings have been obtained by the research's level of execution under stationary settings in a live steam kinetic configuration. This is especially obvious in the application's effective analysis of wet steam flowing in a narrowing, flatter nozzle. This novel method has the potential to greatly advance our knowledge of the complicated dynamics of fluids and greatly aid in the creation of more effective and optimised steaming systems that serve a range of uses in industry.

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