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Experimental study of condensing steam flow in nozzles and linear blade cascade

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ABSTRACT

Experimental investigations of non-equilibrium spontaneous condensation in transonic steam flow were carried out in nozzles and linear blade cascade. For the tests the geometry of the half arc nozzles were used. The linear cascade consists of the stator blades of the last stage low pressure steam turbine. The applied experimental test section is a part of small scale steam power station located at the Silesian University of Technology. The steam parameters at the test section inlet correspond to the real conditions in low pressure part of steam turbine. The static pressure measurements as well as the Schlieren pictures were used to assess the flow field in nozzles and linear stator blades cascade. The capabilities of used measurement techniques were estimated for gaining insight into condensation process in steam flow. The experimental results were compared with numerical calculations carried out by means of an in-house CFD code.

1. Introduction

The presence of the liquid phase in the low-pressure (LP) steam turbines is responsible for energy losses, it generates thermodynamic and aerodynamic losses, as well as erosion in the turbine components and blade failures due to the corrosion effects. Consequently, it results in a reduction of efficiency and reliability of the steam turbine stages. Therefore, an accurate prediction of the loss mechanism due to the steam condensation is a worldwide importance.

The steam properties (steam purity) and the flow unsteadiness, play an important role on the processes of liquid phase formation and its form (fog or coarse droplets), especially on the possible deposition of condensed liquid droplets. It may have some influence on the condensation shock formulation and the generation of shock waves under conditions of supercooled steam flow.

For the last four decades, theoretical [6,9,14], experimental [2,7,8,15] and numerical [10,15] study on the steam condensing flows have been done, also by the group of researchers from the Silesian University of Technology. The numerical method for modeling transonic steam flows with homogeneous and/or heterogeneous condensation was elaborated by them in this time [3,4,12]. The experiments carried out by other researchers for the Laval nozzles [2,8], for 2D turbine cascades [1,11] and for a 3D flow in real turbine [13] were selected to validate an in-house CFD (Computational Fluid Dynamics) code adjusted to the calculations of the steam condensing flows in complicated geometries. The main intention was not to show the best results of possible solutions, but to pay attention to the big sensitivity of the condensation models to the flow conditions (e.g. inlet parameters, steam quality) and implemented gas equation of state. The validation has been performed for many test cases, including flow through the 3D steam turbine stages as well with generally good degree of accuracy.

The aim of this paper is to present an in-house experimental data of the steam condensing flows in nozzles and linear cascade using the experimental set-up of the Silesian University of Technology. The experimental measurement has been carried out under laboratory conditions corresponding to the real conditions prevailing in real operating low-pressure steam turbines.

This work presents the problems existing during the measurements of the non-equilibrium condensing steam flows, especially it is focused on the check of the capabilities of the applied measurement techniques. The in-house measurement results were compared to the calculations obtained by means of in-house CFD code.

2. Experimental facility

The experimental facility is a part of the small steam condensing power plant that is located in the Institute of Power Engineering and Turbomachinery of the Silesian University of Technology.

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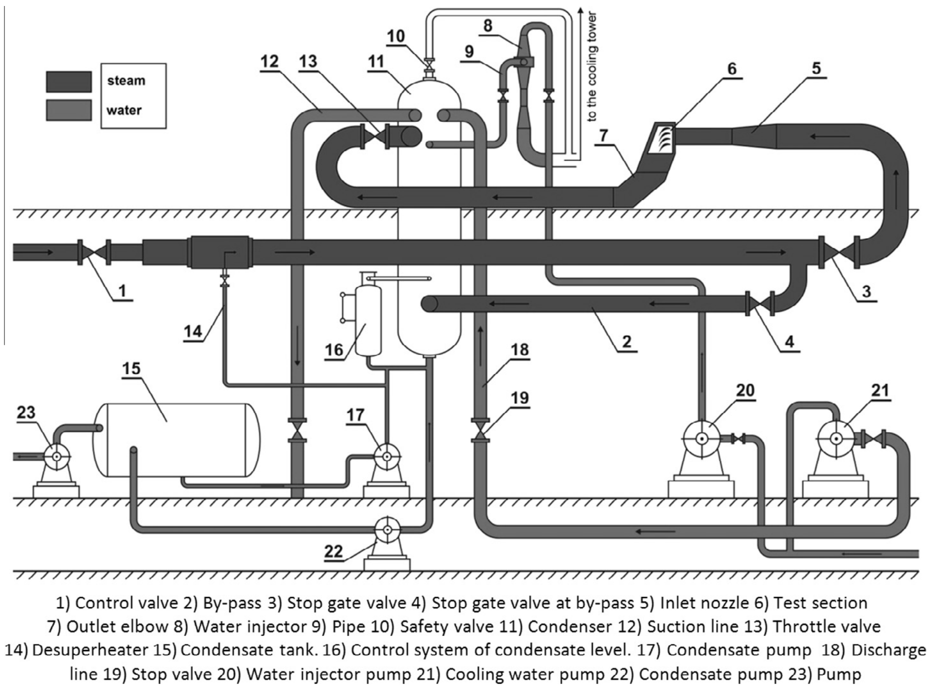

Fig. 1. Steam tunnel with auxiliary devices.

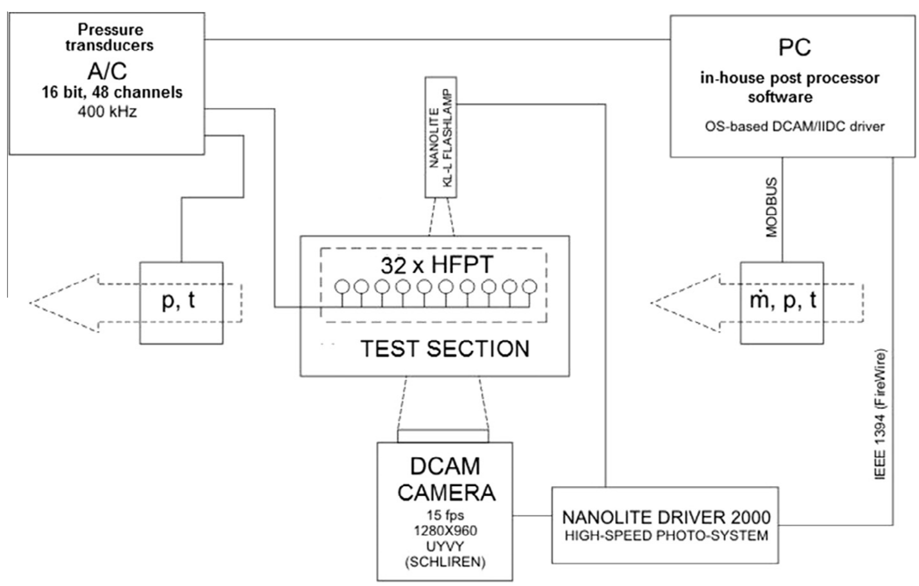

Fig. 2. Scheme of the measurement system.

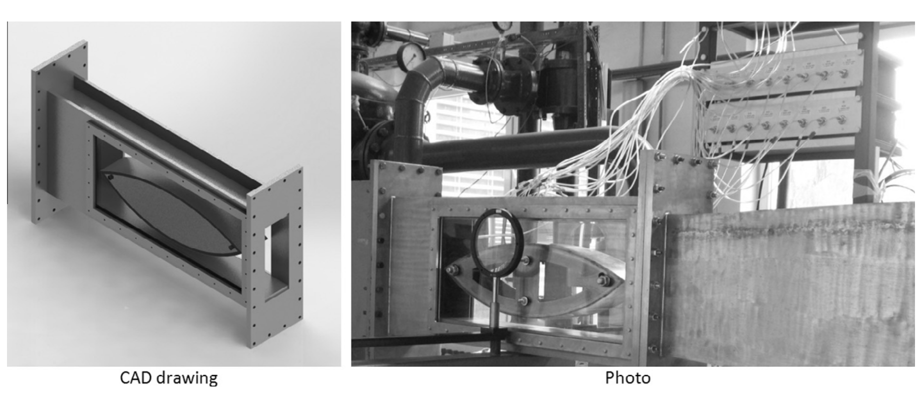

Fig. 3. Nozzles test section.