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Dynamics of steam accumulation

Vladimir D. Stevanovic*, Blazenka Maslovaric, Sanja Prica

University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11120 Belgrade, Serbia

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ABSTRACT

Steam accumulators are applied as buffers between steam generators and consumers in cases of different steam production and consumption rates. The steam accumulator is filled with water and steam and it operates with a sliding pressure. Dynamics of the steam accumulator charging and discharging depends on the accumulator volume, initial and boundary process parameters and condensation and evaporation rates. The non-equilibrium numerical model of steam accumulator is developed with the aim of predicting a steam accumulator capacity and as a support to the design of a control system. The model is based on the mass and energy balance equations for each phase and closure laws of phase transitions. The applied methodology is new regarding the commonly used equilibrium approach. The steam accumulator pressure transients are predicted for the case of periodic variable steam supply to a coal drying plant. The influence of the inlet steam enthalpy on the water mass and level change is investigated. The importance of the non-equilibrium evaporation and condensation modelling for the reliable prediction of steam accumulator transients is demonstrated by examples of charging and discharging tests.

1. Introduction

Steam accumulators are used in industry and power plants in order to adjust differences between steam production and consumption rates. The steam accumulator is filled with water and steam (Fig. 1). The accumulator is being charged in periods of lower steam consumption or surplus of steam production, where the pressure in the accumulator increases and the steam condenses. In periods of an increased steam consumption that is not covered with the production rate, steam is discharged to the consumer, the pressure in the accumulator decreases and water in the accumulator adiabatically evaporates. Therefore, the steam accumulator operates with sliding pressure. Without a steam accumulator, the steam generator would have to operate at a power that should provide steam for the highest consumption, while in the periods of lower consumption the excess steam would be discharged, since the steam generator usually cannot follow rapid dynamic power changes. Obviously, the application of steam accumulator substantially increases the energy efficiency of steam supply. There are numerous examples of industrial processes with periodic variable steam consumption, which require the use of steam accumulators, such as dye works in textile industry [1], glass making, rubber vulcanisation and tobacco processing [2]. In metal manufacturing the steam accumulators are used to accumulate the periodically produced steam and to supply it to industrial consumers with steady or transient steam consumption [3]. An application of the steam accumulator in an industrial boiler plant is reported in Ref. [4]. The plant supplies saturated steam to printing and dyeing mills with variable steam consumption. The steam accumulator enables economic plant operation and stabilised load levels in several time segments for a whole day. Benefits of the thermal energy storage in a steam accumulator coupled with electric boilers is analysed in Ref. [5] for an example of pulp and paper industry. The electricity is consumed for steam generation and storage during night-time hours of lower electricity price, while the accumulated steam is supplied from the accumulator to the process during day hours of higher electricity price. The steam accumulators are also used as a source of steam that performs work during a certain time period, as in case of aircraft catapulting at air carriers, or is used in the thermal power plants for the electricity production during peak loads [6]. Fast reaction times and high discharge rates make steam accumulators a promising option for compensation of fast transients in insolation for solar thermal power plants [7,8]. The application of the steam accumulator in two solar thermal power tower plants under construction in China is presented in Refs. [9,10]. The two-phase refrigerant accumulator is a key component in the automotive air conditioning system [11]. Its primary function is to store excess refrigerant mass to ensure system capacity over a large range of operating conditions.

* Corresponding author. Tel.: +381 11 3370561; fax: +381 11 3370364.
E-mail addresses: estevavl@eunet.rs, vstevanovic@mas.bg.ac.rs (V.D. Stevanovic).

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