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Analysis, experiment and application of a power-saving actuator applied in the piston type energy recovery device

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HIGHLIGHTS

- Power-saving water hydraulic actuator is innovatively used in piston type ERD.
- Driving power of RS-ERD can be reduced up to 90.3% by avoiding previous idle work.
- Performance of RS-ERD with water hydraulic actuator is experimentally investigated.
- Reliability of water hydraulic actuator is verified in real case of NF-ERD system.

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ABSTRACT

A piston type energy recovery device (ERD) can reduce the power consumption of seawater desalination system effectively, but the necessity of the oil hydraulic actuator for the ERD weakens the economics of the device and brings peripheral issues such as increased footprint. In this paper, a water hydraulic actuator driven by the high pressure brine of the desalting system is proposed to resolve the above problem and applied in the piston type reciprocating-switcher ERD (RS-ERD) to testify its effectiveness. The superiority evaluation proves that a reduction of up to 90.3% of the driving power consumption can be obtained by using the water hydraulic actuator, whose capital and maintenance costs are significantly lower than that of the oil hydraulic actuator. The experiments in the emulate test platform show that the RS-ERD with the water hydraulic actuator is operationally feasible and achieves high energy recovery efficiency of above 97%, except the existence of pressure pulsation (23.1%) in high pressure brine stream. Additionally, long term demonstration in the nanofiltration desalination system proves that the RS-ERD with water hydraulic actuator has a good operational reliability whose pressure pulsation has been dramatically minimized to 3.3% while maintaining the efficiency as high as 96%.

1. Introduction

In reverse osmosis (RO) desalination systems, an isobaric energy recovery device (ERD) is commonly incorporated [1–3] for significantly reducing the power consumption of the system [4,5]. Currently in the market place, there includes two types of isobaric ERDs, one is the piston type and the other is the rotary type. The piston type ERD usually comprises three main parts, the switcher, two cylinders and a check valve nest [6,7], while the rotary type ERD (as PX for instance) typically consists of a high-speed spinning cylindrical rotor with multiple longitudinal ducts and the end covers in the two sides [8].

The main characteristics that the piston type ERD differs from the rotary type ERD are that the former one achieves its pressure exchanging between the high pressure brine and the feed seawater by regularly switching the forward and backward strokes of the switcher [9], while the latter one realizes its energy recovery function by continuously rotating the rotor between the end covers [8,10]. This paper focuses on the piston type ERD which has been widely used in large scale RO desalination projects [11–14], due to its exceptional efficiency, operational flexibility and high availability [15–17].

Typical products of the piston type ERD include the Dual Work Exchanger Energy Recovery (DWEER), the SalTecN and the RO Kinetic [18–20]. As the core component of the device, the switcher adopts different driving approaches or systems. For the DWEER (whose switcher is expressed as the LinX valve) [21] and SalTecN products, an oil hydraulic actuator and the auxiliary pump station are incorporated in their driving system; and an alternative drive device for the DWEER is the electric actuator [22]. Differently, the RO Kinetic adopts a mechanical driving approach including an electric motor, a driving rod and a group of planetary gears [23]. All the driving approaches own their

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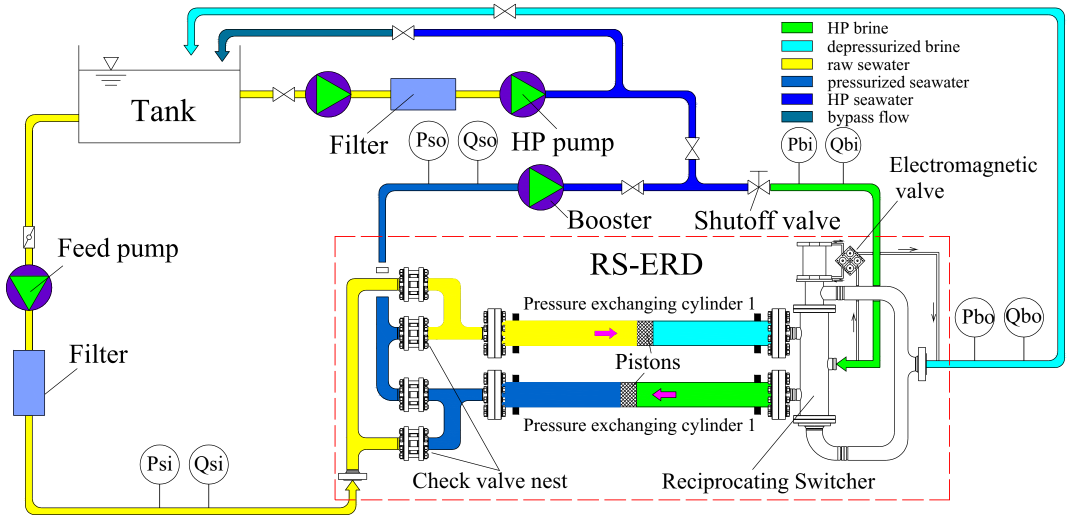

Fig. 1. The flow diagram of RS-ERD emulate test platform.

respective characteristics and can interchange with each other. No matter which approach it is, the driving power is converted from electricity, and the lesser the conversion steps, the higher the mechanical efficiency.

As it is known, the oil hydraulic driving system is a well-developed technique in the industries and famed for its good operational reliability. However, the oil hydraulic system, when integrated into the piston type ERD, is characterized by intermittent motions with relative high frequency and confronted with the a series of problems [9]. Firstly, the existence of the oil hydraulic pump station would result in an increased capital cost and noise level for the ERD device. Secondly, auxiliary cooling equipment is needed to control the temperature of hydraulic oil within a reasonable range, which will increase the maintenance cost of the device. Thirdly and most importantly, the oil hydraulic system of the ERD needs to work both in the short switching process and in the long period pressurization process (above 90% of the cycle). However, only the work in the switching process can be confirmed valid for the ERD device. Hence, a plenty of hydraulic energy will be wasted as idle work which will finally be added to the water production cost [24].

In order to resolve the above problems associated with the oil hydraulic actuator and to reach the goal of minimizing the operational costs of the ERD, a water hydraulic actuator is proposed, which uses HP brine from the desalting system as the medium to drive the switcher to switch in a relative short period. Hence the first task of this paper is to introduce the working principle and give a superiority evaluation about the water hydraulic actuator.

To verify the operational feasibility of water hydraulic actuator and evaluate its effect on the performance of reciprocating-switcher ERD (named RS-ERD), an emulate test platform built for our previous work [9,25–27] has been redesigned by using water hydraulic actuator and electromagnetic valve to substitute the previous oil hydraulic actuator and pump station. The RS-ERD with water hydraulic actuator is experimentally investigated and assessed in the platform in terms of internal leakage, energy recovery efficiency and operational stability. The operational reliability of the RS-ERD with water hydraulic actuator is also demonstrated in a nanofiltration (NF) desalination system for an 18-month operation.

2. Introduction of the RS-ERD and the emulate test platform

The operational feasibility of the water hydraulic actuator is assessed based on the operational performance of the RS-ERD which is tested in the emulate test platform built for the previous work.

2.1. Working principle of the RS-ERD with the water hydraulic actuator

The RS-ERD belongs to the piston type and mainly consists of three parts: a reciprocating switcher (RS), two pressure exchanging cylinders and a check valve nest as shown in the red box of Fig. 1. The RS is the core component of the device for maintaining the continuity and stability of pressure exchanging in cylinders. In order to drive the RS in an energy-saving way, a water hydraulic actuator is adopted which works parallel with the electromagnetic valve to realize the reciprocating movement of the switcher. The water hydraulic actuator is innovatively powered by a small portion of the high pressure (HP) brine which can be gotten directly from the membrane desalting system.

Fig. 2. The RS-ERD in the scene.