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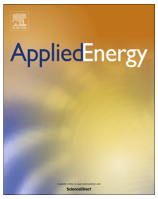

Review

# Regenerative liquid ring pumps review and advances on design and performance

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## HIGHLIGHTS

- Examines the principle of operation of RLR pumps and areas of application.
- Highlights the operational advantages of RLR pumps.
- Reviews the performance challenges of RLR pumps.
- Presents development and improvement of geometrical parameters of RLR pumps.
- Future research and focus on a holistic approach to efficiency improvement.

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## ABSTRACT

The regenerative liquid ring (RLR) pump is a type of rotodynamic machine which has the ability to develop high heads at relatively low flow rates in only one impeller stage. Although the exact principle of operation of this type of pump has been a phenomenon not fully understood, it has nevertheless been widely applied for over a century in areas of liquid pumping. Despite the low efficiency, RLR pumps have several advantages over other turbomachines with similar tip speed due to relatively low manufacturing costs, simplicity, high reliability, enhanced priming behaviour and can in many applications offer a more efficient alternative. Efficiency improvements are key to reducing energy consumption and ultimately combatting the global climate change. This paper offers an extensive review into the development, performance challenges and design improvements of RLR pumps in order to provide some useful insight on future research and next steps, with a particular focus on improving efficiency throughout the pump life cycle.

## Contents

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## 1. Introduction

Pumps are the single largest user of electricity in the industry sector in the European Union [1]. A study on improving efficiency in pumps carried out by the European Commission in 2001 [1], found that pumps consumed as much as 160 TW h of electricity per year, equivalent to 14% of the total electricity consumed in industry and commerce. The energy wasted by those pumps was as high as 46 TW h in 2008 [2].

Centrifugal pumps represent some 73% of all pump energy consumption. The regenerative liquid ring pump (RLR) is, like the centrifugal pump, a kinetic machine. However it can in many applications offer a more efficient alternative [3]. Despite the many advantages over other turbomachines with similar tip speed, one of the main challenges of RLR pumps is to understand and improve the efficiency. In addition the degradation effects due to erosion, cavitation and natural wear life must be fully understood, as it is closely linked to pump efficiency. The rate of wear will tend to be greater during operation away from best-efficiency conditions. For example, larger clean water pumps can on average drop 5% in efficiency in the first five years of operation, partly due to wear [1]. It therefore becomes important not only to improve the hydraulic design of the RLR pump but also to assess efficiency-degrading parameters during its whole lifecycle. This review forms part of novel research into the life cycle assessment of a RLR pump using computational modelling techniques to improve its reliability.

The RLR pump is a type of rotodynamic pump which combines mechanical impulses of the impeller with centrifugal force [4]. The increase in head is achieved through a momentum exchange between the impeller and the pumped fluid [3]. However, in contrast to the centrifugal pump, the pressure rise occurs in the peripheral rather than in the radial direction [5,6]. Perhaps what really distinguishes the RLR pump is its ability to develop high heads at relatively low flow rates in only one impeller stage [7,8]. It shares similar operating characteristics to another pump classification, positive displacement: the power is directly proportional to head, with a maximum power required at shutoff and a very steep, nearly straight head-capacity curve [4,9–11].

RLR pumps are also sometimes referred to as peripheral, side channel, water-ring, liquid-ring, drag, turbine, traction, tangential, vortex and claw-type pump in literature, often reflecting a variation in geometrical design or preference for a theory of the principle of operation [9,12,13].

Fig. 1 shows a schematic of a generic RLR pump. It consists of a radially split casing with an annular channel and an impeller [10] with several, generally 20–50 [7], radial blades around its perimeter. The annular channel is sometimes separated into the side channel, which are the channels at either side of the impeller, and the tip channel, which is the channel spanning all the way around the periphery of the impeller.

The inlet (suction) and outlet (discharge) ports are separated by a ‘stripper region’ with close clearance to the impeller, which prevents the fluid from flowing back from the outlet to the inlet, so only the fluid between the blades is allowed to pass through. The clearances between the impeller disk and the casing are kept to a minimum to prevent leakage from the high-pressure side back to the low-pressure side [12,15,16].

The increase in head is achieved through an exchange of momentum between the impeller and the fluid. The fluid circulates through the blades as shown in Fig. 2. The fluid that enters into the lower blade space from the side channel in the direction parallel to the machine axis receives angular momentum by the rotating blades before it is radially discharged at the blade tip. The blade pocket fluid then transfers the angular momentum to the peripheral flow in the annular open channel, which is driven by shear force due to the rotating blades. The fluid that transfers all the momentum enters into the following blade space, again in an axial direction near the blade hub. This energy exchange process repeats itself from the inlet to the outlet ports, thus the static pressure continues to increase. Consequently, the fluid follows a helical passage throughout the flow channel (Fig. 3). It is this repetitive motion of the fluid (regeneration) that allows these pumps to generate high heads at relatively low specific speeds in a single impeller stage.

## 2. Background

### 2.1. History

It is hard to pinpoint exactly when the RLR pump was invented due to its many names and forms. Perhaps one of the earliest concepts to make use of the regenerative operational principle in the

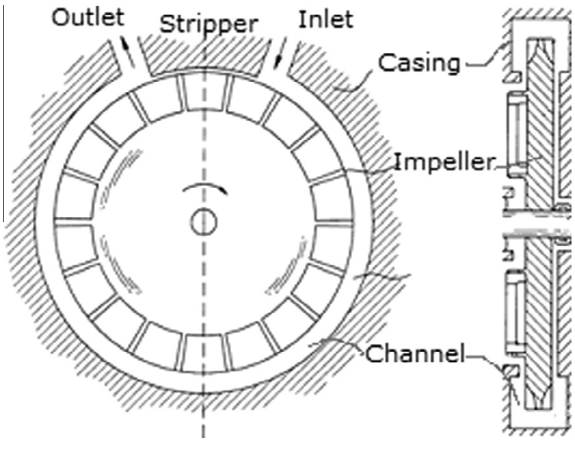

**Fig. 1.** Schematic of a typical regenerative pump [14].