Study on Performance Analysis and Optimization Strategy for Conveying System of Hydraulic Dredgers

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ABSTRACT

As a premise research, performance and optimization strategy for conveying system of hydraulic dredgers is studied. Calculation method of conveying system performance is formed by combing pump performance and pipeline resistance formulas according to available researches and engineering experience, with the restriction of pipe blockage, pump cavitation, and excavation capacity. Three cases of different operation scenarios are applied to verify and analyze the performance of dredger conveying system. Calculated conveying performance is in good agreement with measured in each case. The results show specific properties of dredger conveying system: there is an optimal working point for conveying system for each pump speed(s) under certain operation conditions, characterized by the maximum production and the minimum energy consumption; there is a perfect pump speed when conveying capacity and excavating capacity is matching, which leading to production maximized and energy consumption minimized at the optimal working point; different operation mode (pump combination) leads to different conveying performance. Therefore, the basic idea and strategy of conveying system optimization is to determine the appropriate operation mode, find the perfect pump speed, and keep the optimal working point. Meanwhile, excavation operation shall be kept or adjust to match conveying capacity as much as possible.

KEY WORDS: Dredger; conveying system; optimization; production; energy consumption.

INTRODUCTION

Hydraulic dredger, represented by Trailing Suction Hopper Dredger (TSHD) and Cutter Suction Dredger (CSD), plays an indispensable role in many construction projects of waterway dredging, port construction, land reclamation, river management, contaminated sediment cleaning, submarine pipe laying, trench backfilling, deep sea sand extraction, geological mining, coastal defense construction, etc. (Zhang, 2003). It is a real challenge to keep a dredger working with high efficiency, due to its complex composition and operation processes, coupled with the changeable geological, hydrological and other working conditions. Traditional dredging operation depends on experience and judgment of operators, and operating performance differs greatly between operators (Tang et al., 2008; IHC 2004). As theories and control technology develops, dredging is marching from period of traditional experience and artificial control toward period of automation and intelligence. Neural network, genetic algorithm, expert control, fuzzy control and other intelligent control technologies are applied to solve the problems of working condition variability and complex operation processes, so as to realize intellectualization of dredging operation (Tang et al., 2008; Zhang et al., 2011; Wang et al., 2012; Li et al., 2015). Most of these researches are in exploration stage, and the optimization results depend heavily on pre-training.

Conveying system, composed by slurry pump(s), pipeline, supporting and auxiliary devices, is main energy consumption components of hydraulic dredger, performing the function of suction and discharge of dredged material. Generally, designed slurry pump power can account for 20-40% of the total installed power for trailing (dredging) operation of large and super larger TSHD, while 40-60% for discharging operation (Zhang, 2003); different operating modes of CSD may be adopted due to conveying distance changing, energy consumption of conveying system may account for more than 80% of the total (Li et al., 2017).

As a basis of performance analysis of conveying system, research on mechanism and characteristics of liquid-solid flow in pipeline is a long-term work. Early studies formed formulas combing theory and practice, according to small pipe experiments and field data, with certain application range and limitations. In recent decades, as application of modern research methods, such as large-scale conveying platforms, advanced testing methods and instruments, numerical simulation methods, detailed studies were achieved on the motion mechanism and characteristics under complex working conditions, e.g. special or mixed particles, vertical transport, different flow patterns and their transformation (Li et al., 2005; Chung et al., 2007; Vlasak et al., 2007, 2014; Sobota et al., 2009; Miedema, 2015, 2016a, 2017; Sellgren et al., 2016; Hashemi et al., 2016; Xiao et al., 2016; Li et al., 2018; Xiong et al., 2019; Dabirian et al., 2018). TUDELFT integrated slurry transport experience and achievements in dredging field and developed "the Delft