Energy 123 (2017) 36–46

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Effects of concentration and size of silt particles on the performance of a double-suction centrifugal pump

Zhiyuan Wang, Zhongdong Qian*

State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan 430072, PR China

ARTICLE INFO

Article history:
Received 3 July 2016
Received in revised form
11 January 2017
Accepted 29 January 2017
Available online 31 January 2017

Keywords:
Double-suction centrifugal pump
Silt concentration
Silt size
Performance

ABSTRACT

With the large flow rate and high pump head, double-suction centrifugal pumps are widely used in irrigation pumping stations along the Yellow River. However, the performance of these pumps is affected by the characteristics of silt particles in water flow, which has been seldom studied. Therefore, this paper aims to investigate the effects of the silt concentration and silt size on pump performance by devising a new experiment for a double-suction centrifugal pump. The results show that the pump head and the shaft power are lower compared with that of pure water condition due to the presence of silt, and decrease as the silt concentration and silt particle size increase. Furthermore, at the low flow rates, the efficiency of the pump under silt-laden water condition is found to be higher than that under pure water condition. A relationship is then established as a function of silt parameters for the head reduction factors of the double-suction centrifugal pump. This relationship can help pump manufactures predict the head of a double-suction centrifugal pump for given silt-laden water.

1. Introduction

The silt concentration in the Yellow River is ranked as one of the highest in the world. As the river runs through Northwest China, a region of drought and water shortage, many pumping stations have been built on both sides of the river for agriculture irrigation. Double-suction centrifugal pumps are being widely used in these pumping stations because of large flow rate and high pump head. However, the existence of silt particles within water in the Yellow River would significantly affect the flow pattern in the double-suction centrifugal pump and thus the performance of the pump.

At present, double-suction centrifugal pumps are assumed to operate in pure water without any particles, and the effects of silt particles on pump performance have seldom been investigated. On the one hand, previous research on silt particles in hydraulic machinery focused mostly on silt erosion. For example, Padhy et al. [1–3] investigated the effects of silt parameters on erosion and performance of a Pelton turbine, and proposed that turbine efficiency loss strongly depended on silt size and silt concentration. Thapa et al. [4,5] summarized the problem of sediment erosion for hydro turbines in South Asia and put forward an erosion model for Francis turbines. Qian et al. [6,7] studied the silt abrasion mechanism in a double-suction centrifugal pump and suggested some effective measures to reduce the erosion rate.

On the other hand, the effects of silt particles on the performance of single-suction centrifugal pumps or centrifugal slurry pumps have been studied but not the double-suction centrifugal pumps. With experiments conducted on small-size samples and different types of test rigs, the research showed that pump performance decreased with increasing solid concentration and particle size. Fairbank [8] studied the effects of the concentration and median particle size of solids on the performance of a single-suction centrifugal pump and attributed the head reduction to the difference in the velocities of the liquid and solid particles leaving the impeller. Vocadlo et al. [9] showed that the head reduction was caused by the interactions among particles and mutual effects between particles and fluid. However, Chand et al. [10] investigated a slurry pump and found that the head and efficiency of the pump increased with the addition of solid particles. Kumar et al. [11] analyzed the performance characteristics of a centrifugal slurry pump with multi-sized particulate slurry of bottom ash and fly ash mixtures, and found that the addition of fly ash to the bottom ash slurry improved the performance of the pump in terms of head and efficiency.

Various studies [12–19] found relationships between the pump head and different parameters such as the silt concentration,

* Corresponding author.
E-mail address: zdqian@whu.edu.cn (Z. Qian).

http://dx.doi.org/10.1016/j.energy.2017.01.142
0360-5442/

relative density, particles size. These relationships are based on pump types and the properties of slurries or solid particles, and hence are not universally applicable.

A number of researchers conducted experiments to study the effects of silt parameters on pump performance; however, these studies used single-suction centrifugal pumps or slurry pumps and the medium was slurry. The aim of our study was to clarify the effects of silt parameters on the performance of double-suction centrifugal pumps along the Yellow River; this paper investigated the effects of the concentration and size of silt particles on the performance of a double-suction centrifugal pump which is commonly used in pumping stations.

In the experiment, four silt concentrations and three silt sizes were observed. Based on the results, a relationship was established for the forecast of the head reduction factors of a double-suction centrifugal pump. The relationship would be useful to the pump manufacturing industry, and it provides a method to reduce energy consumption through selection of the optimal pump and ensuring an efficiently functioning system.

2. Materials and methods

2.1. Experimental setup

Fig. 1 is a schematic of the experimental setup consisting of a test pump and driving motor, a water tank, pipes, valves, accessory equipment, and test equipment.

The test pump is shown in Fig. 2. It is a double-suction centrifugal pump, which is widely used in the pumping stations along the Yellow River; the basic parameters are given in Table 1.

In the experiment, the water is drawn from the water tank by the test pump through the inflow pipe, and returned to the water tank after circulating through the test loop. The flow rate is measured by an electromagnetic flowmeter which is installed in the outflow pipe. The outflow valve regulates the flow at the required rate. Six pressure transmitters, mounted on the inflow and outflow pipes near the pump as Fig. 3, are adopted to record the suction and discharge pressures. The flow rate and pressure measurements are read by a data acquisition system controlled by industrial personal computer. The power-measuring device,

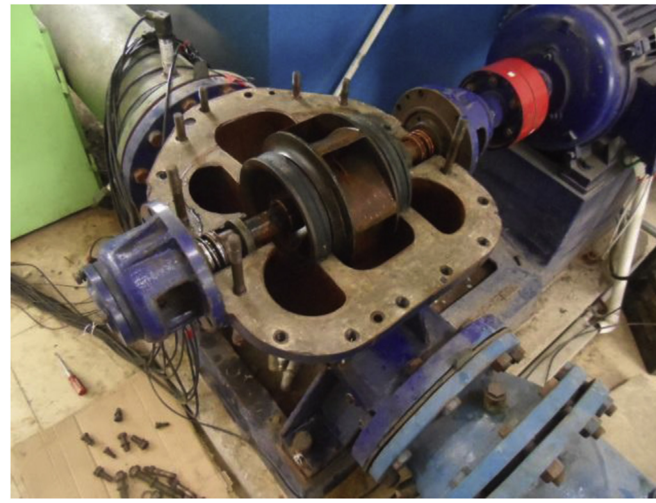

Fig. 2. Test pump.

Table 1
Basic parameters of the test pump.

Parameters	Value	Parameters	Value
Mode number	250S-14	Blades of the impeller	6
Design flow rate	485 m^3/h	Impeller inlet diameter	158 mm
Design head	14 m	Impeller diameter	245 mm
Rated speed	1450r/min	Impeller outlet width	88 mm
Matched power	30 kW	Pump inlet diameter	250 mm
Specific speed	189.8	Pump outlet diameter	200 mm

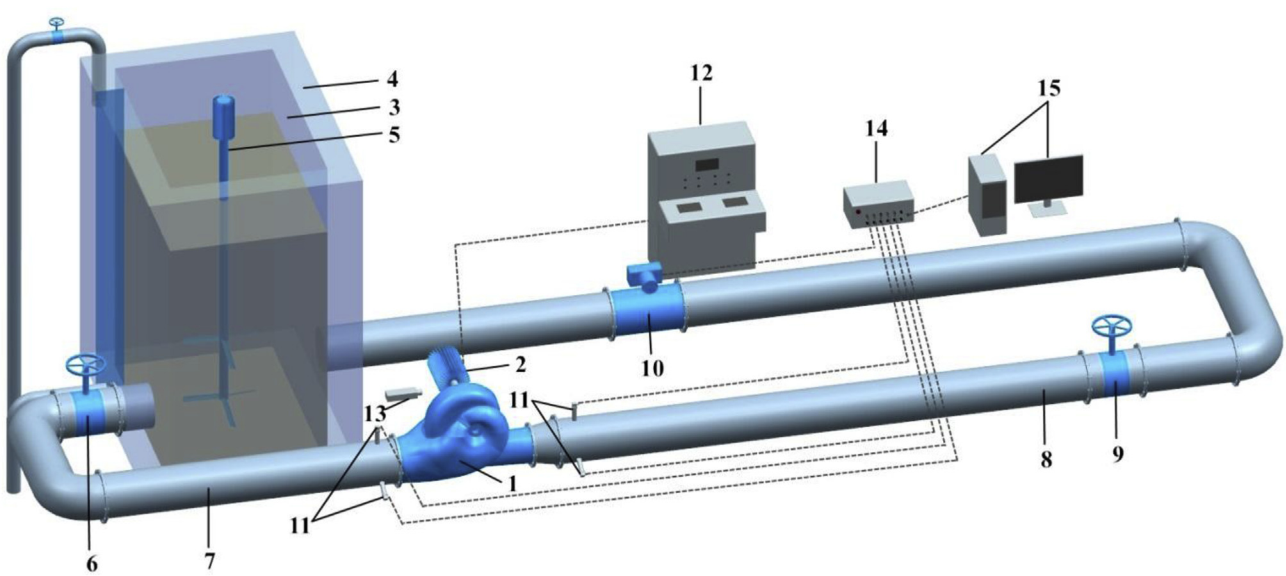

Fig. 1. Schematic of the experimental setup. Description: 1: Test pump, 2: Driving motor, 3: Water tank, 4: Cooling jacket, 5: Stirrer, 6: Inflow valve, 7: Inflow pipe, 8: Outflow pipe, 9: Outflow valve, 10: Electromagnetic flowmeter, 11: Pressure transmitter, 12: Power-measuring device, 13: Precision digital tachometer, 14: Data acquisition system, 15: Industrial personal computer.