

THE APPLICATION OF A PRODUCTION OPTIMIZATION SYSTEM FOR A CUTTER SUCTION DREDGER

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ABSTRACT

The paper briefly introduces the operation principle of the “Cutter Suction Dredger Dredging Technique Computer Aided Decision-Making Analysis and Production Optimization System”. This is solely developed and researched by the China Communications Construction Group, and highlights the popularization and application of this system on new and old dredgers of China in the past 3 years. According to the 11 user reports from Tianjin, Shanghai and Guangzhou dredging companies, the system proved its efficiency by improving the average production rate per hour by 30% compared with the original. This system distinguishes itself by its installation on the dredger, providing operation techniques with on-site decision-making analysis and production optimization assistance based on trial dredging at the site. Computers with an Ethernet network on board are capable of collecting dredging data, reporting different bottom soil type areas and automatically recording optimized dredging parameters corresponding to soil types. The captain could determine the operation techniques according to optimized data and instruct the operators’ work which could guarantee on-site maximum production for the Cutter Suction Dredger (CSD). The great volume of on-site dredging data stored makes it possible for the dredging experts to do research on the dredging methods and mechanism.

Key words: Cutter Suction Dredger (CSD); Dredging Technique; Computer Aided Decision-Making Analysis; Production Optimization; Soil Type Change;

INTRODUCTION

The kernel or core of dredging technology is to be able to deal correctly with the interaction between machinery and soil so as to raise working efficiency, decrease costs, improve the working precision and reduce over-dredging. There is also a need to improve the efficiency and service durability of dredging machinery, and correctly deal with the contradiction between dredging activity and the environment. “The Intelligent Monitoring and Control and Computer-aided Decision System” and “Highly efficient and Durable Dredging Machinery”, are patented technologies developed by the China Communications Construction Group Co., Ltd. They are possessed by most of the large and medium-sized trailing suction hopper dredgers and cutter suction dredgers in China that are associated with dredging 265 million m³ of sand a year. This technology helps with China’s dredging and apparently adds “eyes” and “brains” to a dredger by scientifically and reasonably tackling the dialectic and consolidated relationships between dredger operators, the dredger, dredging machinery and soil types. This type of technology ensures that the production of a dredger is high and steady and that the major dredging machinery operates in a highly efficient manner and is durable in spite of the fact that dredging operators in China are generally less qualified. The application of these technologies renews the traditional concepts and technology in China’s dredging field and is a breakthrough in the industry’s development. This not only improves project management but also ensures the safe operation of machinery and equipment.

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The technology has been applied on 28 dredgers and 8 newly built dredgers of CCCG and generally adopted in the design and shipbuilding of dredgers in China.

BASIC PRINCIPALS OF THE SYSTEM

The CSD Dredging Technique Computer Aided Decision-Making Analysis and Production Optimization System comprises a monitoring and control system and a computer-aided decision analysis system. The monitoring system mainly monitors the cutter, submerged pump, main pumps, traveling winch, discharge pipes, etc.; the positioning system mainly monitors the position of the vessel, direction of cut, cutter ladder and the three-dimensional position of cutter, spuds, etc. The sub-systems independently carry out signal acquisition and control via the field bus system while the computer system acquires data via LAN and conducts data processing. The whole system can be monitored during operation and the necessary data obtained through an integrated computer-human interface provides the operator with computer-aided dredging decisions.

What's more important, the CSD Dredging Technique Computer Aided Decision-Making Analysis and Production Optimization System sets up a computer-aided decision analysis model as well as the monitoring and control functions. Its fundamentals are as follows:

Statistical Analysis Modeling

The system first draws curves of time-monitor parameters, discriminates reliable data as per certain rules then makes an analyses of valid data. Lastly it establishes the mathematical relationships between any parameters by way of mathematical statistics.

These oscillation curves illustrate the effects of the revolving of the cutter, side swing speed, cut thickness and other effects relating to the production. This data features time changes and random uncertainty that are represented by random oscillating characteristics. The reliable data discrimination and the analysis of valid data are based on the following principles:

- An event occurs several times.
- Filtration of small probability events.
- Data outside of the set limits is deleted.

Curve Fitting Modeling

The system can give quadratic, cubic and point conic fitting functions by the method of least squares.

Modeling for Extreme Computation and Optimization using the Fuzzy Theory

After getting the analytic curves, the system will make an analysis and judgment and give an optimum option.

Extreme Computation

After curve fitting, the maximum of each fit curve will be calculated using the Newton iteration method.

Optimization using the Fuzzy Theory

Fuzzy Evaluation and Looking for the Optimum Parameters

In the computation of the optimum concentration, different modes of operation may have different optimum production figures which need to be evaluated using the overall evaluation algorithm for the most effective operation mode.

The overall evaluation algorithm uses the fuzzy decision theory to make a fuzzy evaluation of pump revolution, load on the diesel engines, resistance coefficient and operating conditions of the diesel engines, to give an overall evaluation value. The biggest of the values obtained being the optimum.

Modeling for the Prediction of the Suction Concentration of Submerged Pump

Generally speaking, the concentration meter and flow meter mounted on a CSD are relatively distant from the suction inlet of the submerged pump and the values displayed on the concentration meter, in reality, lag behind current operations. In order to get the concentration values at the suction inlet on time, the concentration figure at the suction inlet will be predicted based on the suction vacuum of the submerged pump, concentrations read at the concentration meter and flow reading at the flow meter. The principle of communication between vacuum and concentration levels will change with changes in soil types. However, the system will adapt to such changes in soil types by using an adaptive process.

Model of Average Concentration of the Mixture in the Pipes

Generally, operators cannot know the actual status in the suction pipes. They can only use data read at the concentration meter or suction vacuum of the submerged pump to control the production. In fact, what they control is instantaneous concentrations. And for the status in the pipes, instantaneous high concentrations won't cause unsteady flow patterns of the mixture in the pipes, only long periods with high concentrations will cause the delivery to be unsteady. This system simulates the delivery patterns of the pipes and sets up a model of simulated concentrations in the pipes. Maybe this model is not very precise, but, to some extent, it can reflect the actual status of the pipes.

Intelligent Searching for the Maximum Restricted Concentrations for Cutting and Delivery

The computer searches for the maximum working efficiency within a certain time limit by the method of optimization. The average concentration value at this maximum efficiency will then be displayed on the graphs as an optimal concentration for operators' reference. When a new maximum production level within a new time period occurs, the system will update the operating parameters.

- The system also automatically searches for the maximum restricted concentration and minimum restricted velocity of flow by means of optimization. The searching is based on the following principles:
- Concentration value is greater than the optimum concentration value;
- The descending slope of velocity line is greater than a set value (defining the concept of abrupt decline);
- The climbing slope of pumped concentration is not less than a set value (defining the concept of continuous climbing);
- Pumped concentration is greater than the average concentration in the pipes (defining the concept of concentration greater than that in the pipes).

APPLICATION FOR DREDGING PROJECTS

The CSD Intelligent Dredging Monitoring and Control and Aided Decision System has been applied onboard 28 large and medium-sized trailing suction hopper dredgers and cutter suction dredgers and installed on 8 newly built dredgers. Its application is the first example of using “home-made” dredging monitoring and control systems. It has achieved remarkable economic and social benefits, and raised the information and intelligence technology in China’s dredging industry to a new level.

The data acquisition, analysis and optimizing functions of the system play an important role in how working efficiency under different soil conditions can be improved. The results of the analysis and optimizing functions can be displayed on the positioning system interface. This will directly instruct the operator to adjust operating parameters according to soil and position so as to keep the cutting concentration and production rate at an optimal level for the defined section based on the current capacity of the equipment. This greatly reduces the dependence on experience and improves the working efficiency.

The CSD Dredging Technique Computer Aided Decision-Making Analysis and Production Optimization System has been installed on dredgers Jin Hang Jun 217, 218, 215, 221 of CCCC Tianjin Dredging Co., Ltd. and Xin Hai Bao, Hang Jun 2001 of CCCC Shanghai Dredging Co., Ltd. The production efficiencies of these large cutter suction dredgers have been improved under the guidance of optimum dredging parameters given by the system. The system has been used in the dredging projects at Qinhuangdao Port, Huanghua Port, Caofeidian, etc.

Application in the Sand Dredging Project at Fangcheng Harbor by Jin Hang Jun 218 during the 2003 to 2005 Period.

From August 2003 to June 2004, the Dredger “Jin Hang Jun 218” dredged sand and rock alternately at Fangcheng Harbor. Sand dredging and reclamation totaled 1769.5 running hours. The volume of sand dredged was 1.8524 million m³ at an average production rate of 1046m³/h. During the dredging and reclamation of sand the system was used to give recommended values for some of the dredging parameters based on a trial dredging decision analysis. The concentration of the material was raised from 8-15% to 20-35% and the average production rate was raised by 36.19%, from 768m³/h to 1046m³/h while continuing to keep a steady velocity.

From January 2004 to November 2005, the vessel was totally employed on cutting rock for 6787 hours at Fangcheng Harbor. The accumulated volume of rock dredged was 1,913,682m³, with an average production rate of 281.96m³/h. The average production rate was improved by 36.21% from 207m³/h before the application of the system.

Dredger “Jin Hang Jun 215” in 2005

From February to April, 2005, the dredger executed dredging works in Dayaowan Harbor at Dalian. The system was used to give recommended values for some dredging parameters based on a trial dredging decision analysis. Based on keeping a steady velocity, the total running hours were 708.2h, the total volume of sand dredged was 530, 993m³, and the average production rate was raised by 29.6%, from 578.5m³/h to 749.78m³/h.

On April 20, 2005, the dredger was mobilized to Qinhuangdao Port and a trial dredging was conducted on April 22, 2005. The trial dredging lasted for 15.8 hours, the volume dredged was 6400m³ giving an average production rate was 405m³/h. After recommended values for the dredging parameters were given by the computer-aided decision system, the average production rate was improved to 773m³/h.

On September 6, 2005, the dredger was moved to Caofeidian and from September 6, 2005 to November 15, 2005, executed the dredging works. Total dredging time was 114 hours, for a total of 2,414,366m³ of dredged sand. An average production rate is 2,110m³/h.

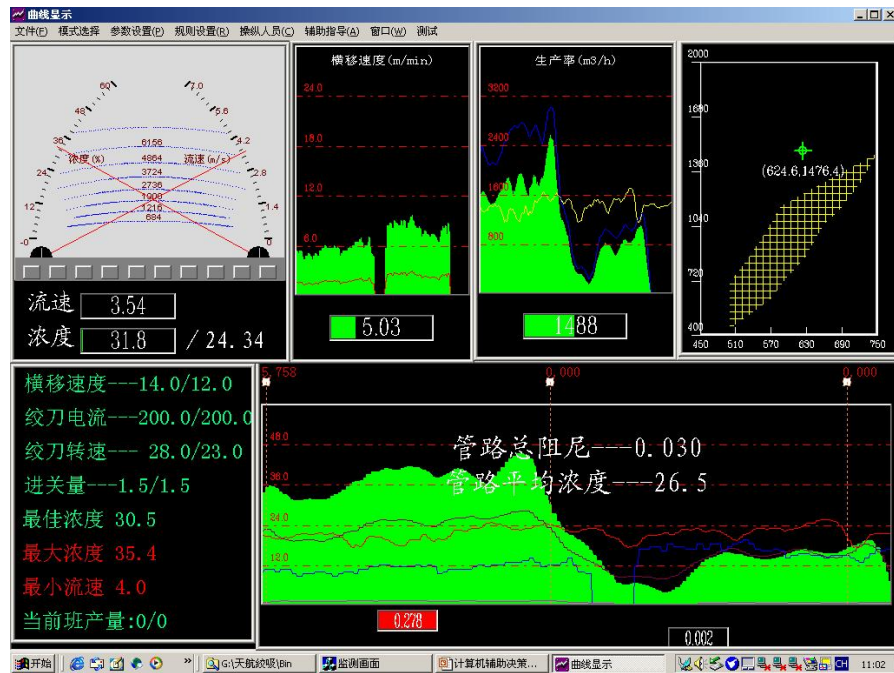


Figure 1 Real-time Monitoring Curves of the Dredging Effects of the Dredger “Jin Hang Jun 218”.

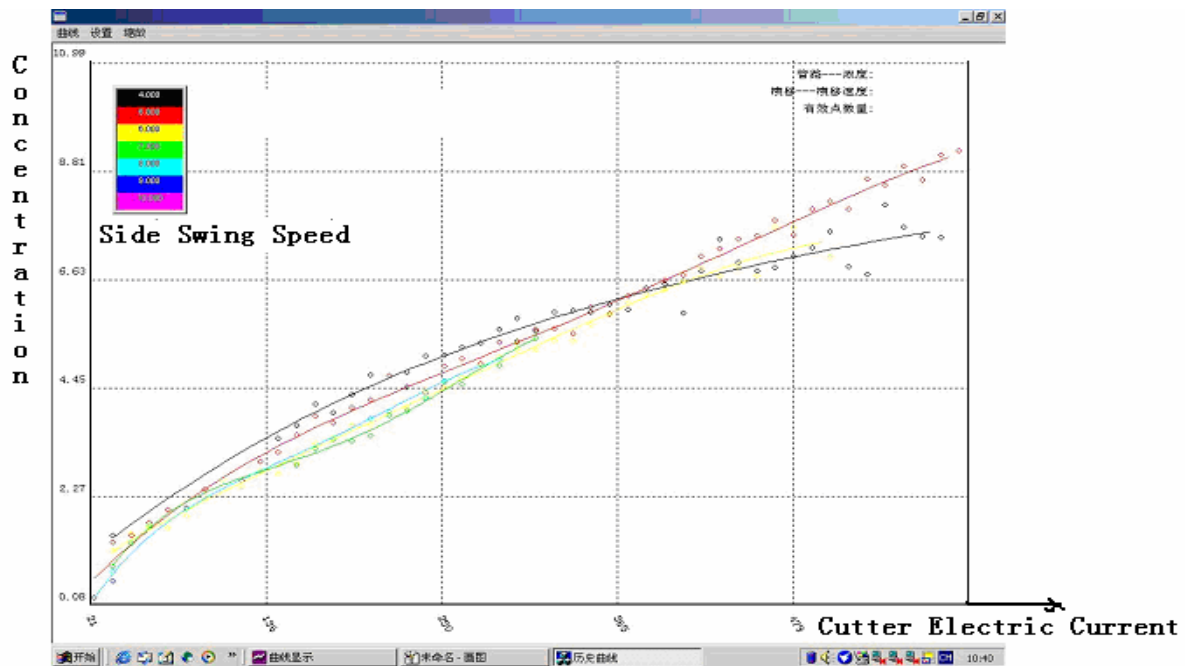


Figure 2 Diagram of Relation Curves among Rock Cutter Electric Current, Side Swing Speed and Concentration.

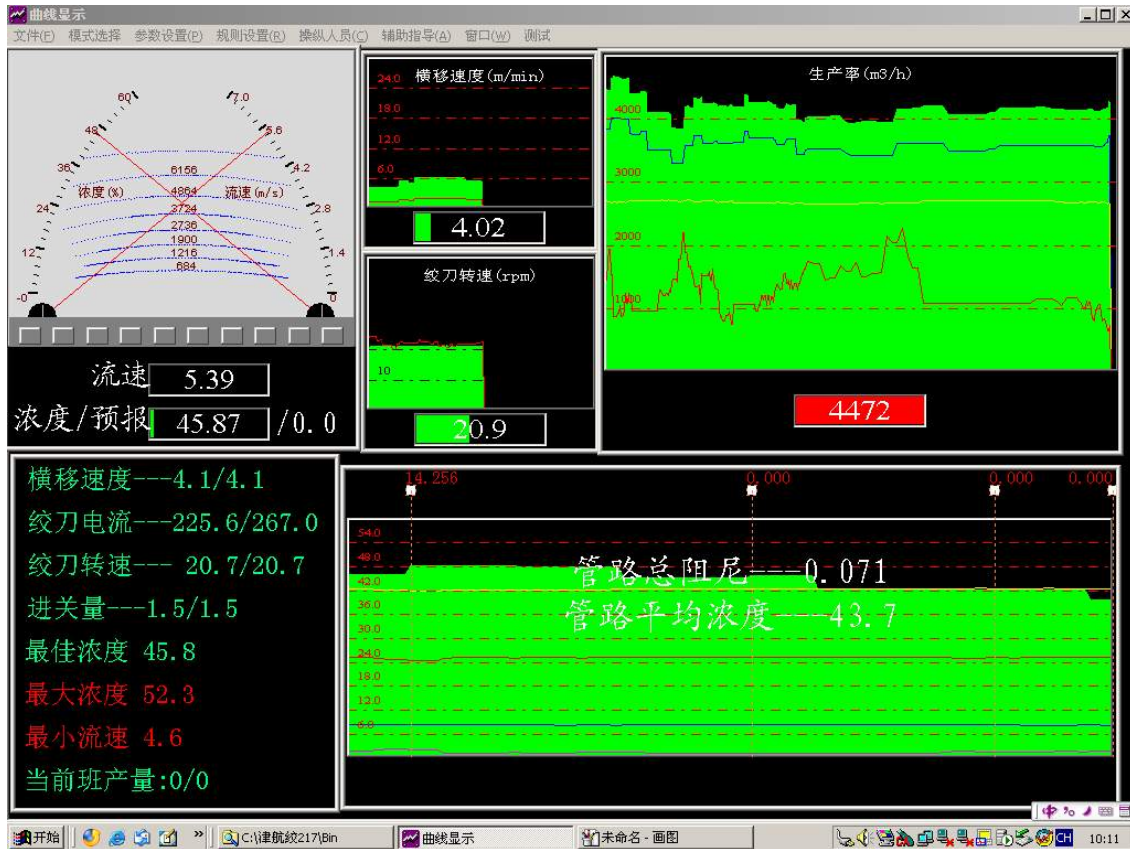


Figure 3. Real-time Monitoring Curves of the Dredging Effects of the Dredger “Jin Hang Jun 215”.

Operations of the Dredger “Jin Hang Jun 217” in June 2005

From January 2005 to October 24, 2005, the dredger executed dredging works with the application of this system. The total dredging hours were 3602.2h and the volume dredged was 1,994,159m³. The average production rate was raised by 25.9%, from 439.6m³/h before the application of this system to 553.6m³/h while keeping a steady velocity.

APPLICATIONS IN NEW-BUILT DREDGERS

Before the development of these technologies, large-sized dredgers had to be built by an overseas shipyard. At present, we have the necessary initiative for the design, development and building of large dredgers for the application of these technologies. In 2005, the newly built cutter suction dredgers “Tian Shi”, “Tian Bao”, “Tian Cheng”, “Tian Bo”, “Tian Jun” were designed and built locally with the application of this system. All of them have now been put into operation. The following Figure 5 is the integrated control system installed on the Cutter Suction Dredger “Tian Shi”.

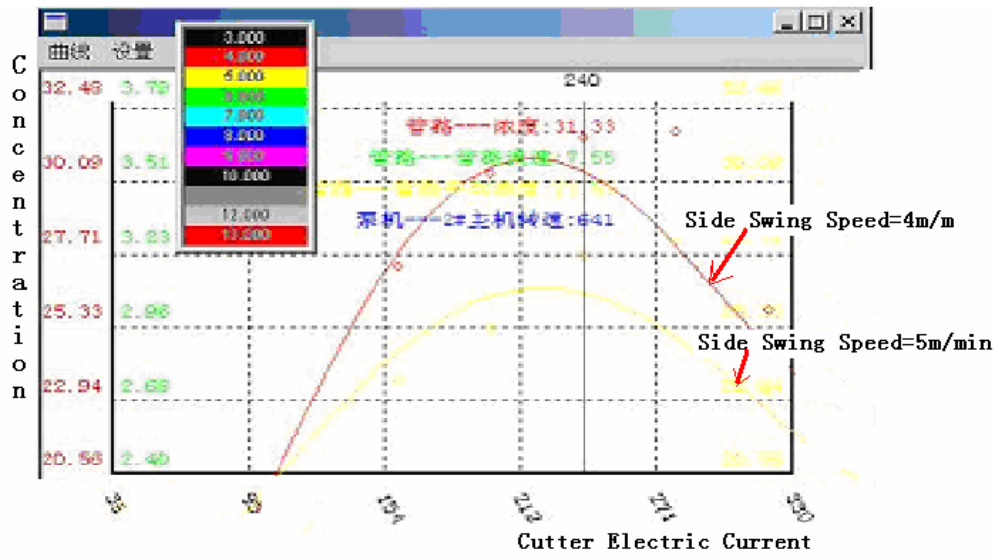


Figure 4. Diagram of the Relation Curves for the Cutter's Electric Current, Side Swing Speed and Material Concentration for the Dredger "Jin Hang Jun 217".



Figure 5. Integrated control system.

