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CHINA COMMUNICATIONS CONSTRUCTION

# FEASIBILITY STUDY OF A TRAILING SUCTION HOPPER DREDGER'S SHIPPING PARAMETERS - ANALYSIS BY PROGRAMMING

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**The trailing suction hopper dredger's working time is divided into two parts : the dredging time and the sailing time. Usually, the sailing distance is fixed, and the sailing time is fixed too. So how to control dredging time based on the mud increasing condition in hopper to improve the production efficiency of the whole working cycle is the problem we need to solve.**

**The solution method I propose is calculating the dredging time based on construction parameters by programming.**

## 1、 Calculating mud volume in hopper

Ship's draft and the liquid level height in hopper are gathered by sensors and liquid level radars. Using these two parameters the mud volume in hopper can be calculated through the displacement method.

$$W = \frac{G - V \times r_w}{r_s - r_w}$$

$G$ —ship displacement ( t );

$V$ —hopper capacity (  $m^3$  );

$r_w$ —water density, take 1.025 (  $t/m^3$  );

$r_s$ —undisturbed soil density (  $t/m^3$  ).

## 1、Calculating mud volume in hopper

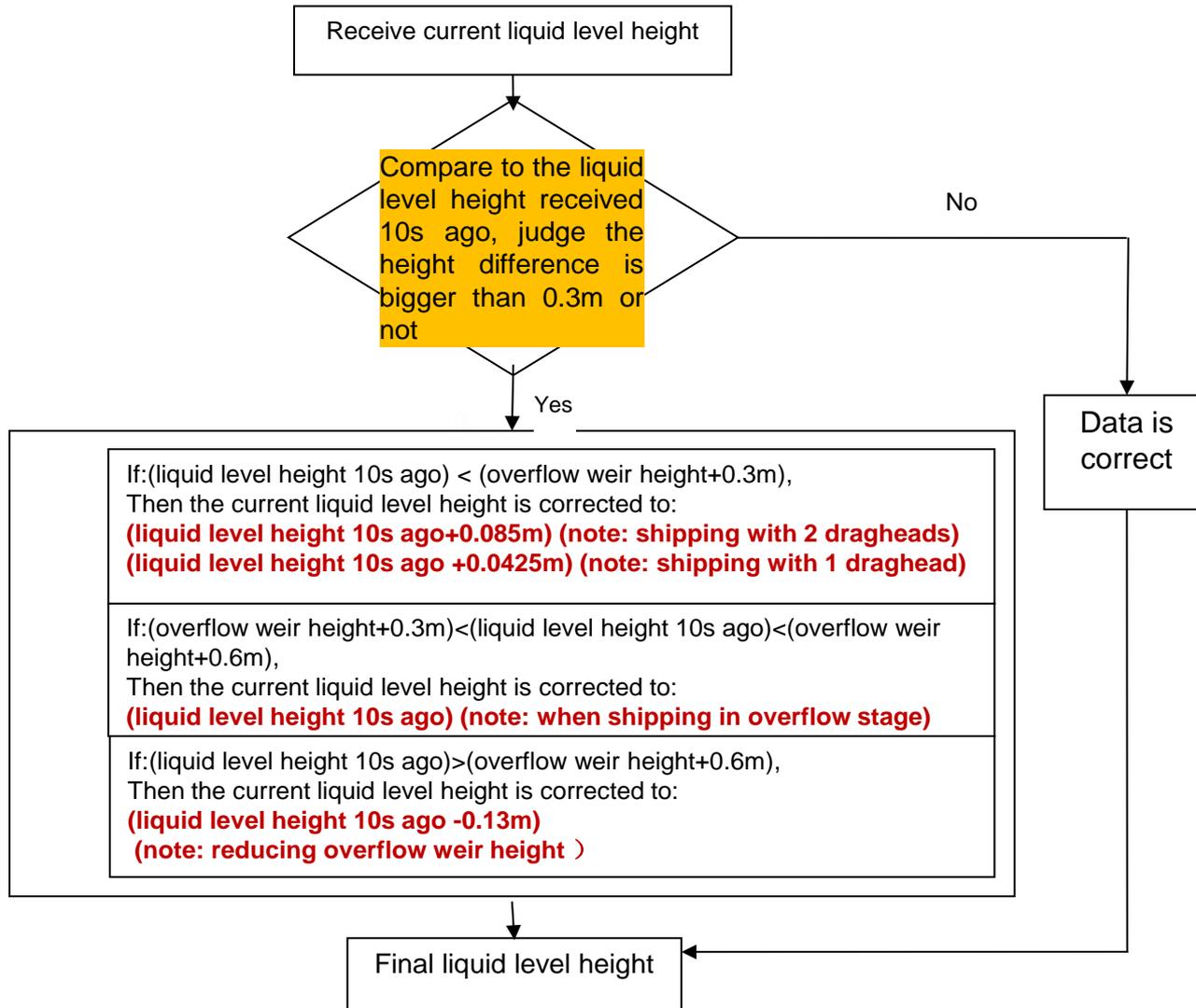
But during shipping process, there is a lot of turbulence in the hopper when pumping the slurry in, which makes the liquid level height gathered by radar fluctuates a lot and further leads to errors in the hopper capacity, so the mud volume calculated through displacement method is not accurate.

In order to calculate the mud volume in hopper accurately, we need to correct the liquid level height. The specific method is : **do correcting based on the mud shipping stage and the height changing situation of the overflow weir.**

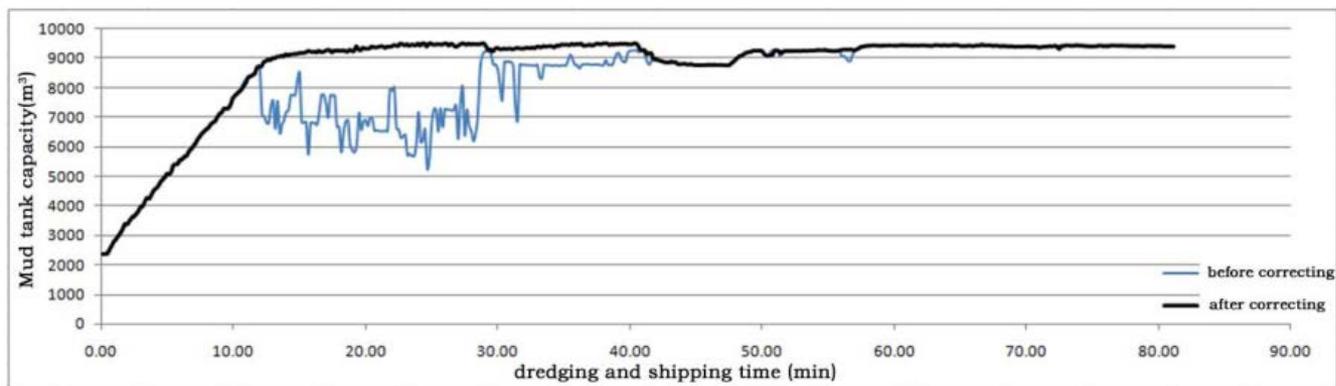
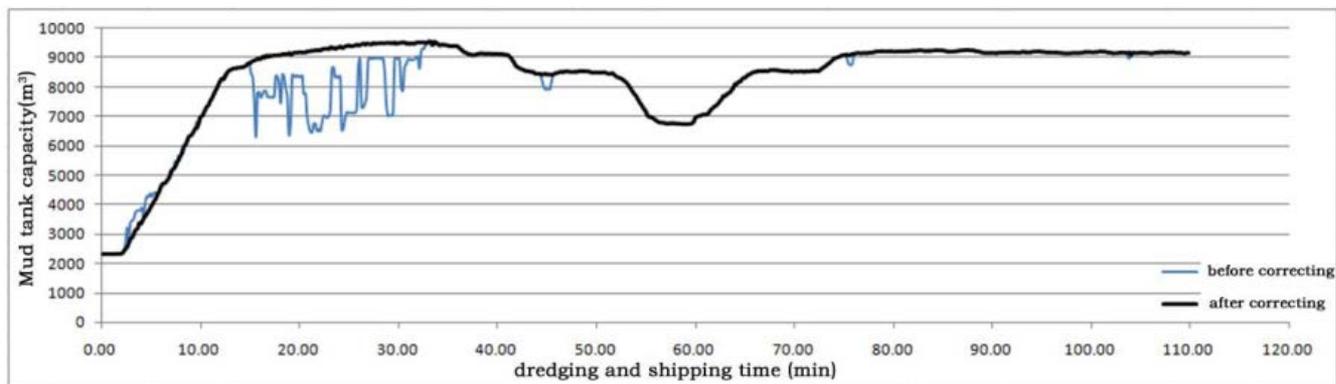
**After comparison tests for several kinds of methods, the most accurate correction process is summed up.**



## Liquid level height correction process



## 1、Calculating mud volume in hopper



Comparison chart of hopper capacity before and after correction

## 2、Fitting increasing curve of mud in hopper

The mud volume in hopper can be calculated accurately based on corrected hopper capacity. We calculate the mud volume in hopper each 10s, and according to all of the calculated mud volume values, we can figure out one equation which describes the increasing trend of mud load in hopper through the least square method.

Set mud increasing curve equation is:

$$y = ax^2 + bx$$

x—dredging time (10s) ;

y—mud volume in hopper (m<sup>3</sup>) .

1

Set  $y_{real}$  as real mud volume in hopper;

Set  $S$  as sum of variance of  $y_{real}$  and  $y$ , then:

$$S = \sum_{i=1}^n (y_{real} - y_i)^2 = \sum_{i=1}^n (y_{real} - ax_i^2 - bx_i)^2$$

2

## 2、Fitting increasing curve of mud in hopper

When  $S$  is minimal, the coefficients  $a$  and  $b$  fit the increase trend of mud in hopper, so according to the extreme principle, calculate the partial derivative of  $a$  and  $b$  respectively, and the partial derivative equals to 0:

3

$$\frac{\partial S}{\partial a} = \sum_{i=1}^n (2x_i^4 a - 2x_i^2 y_{real} + 2x_i^3 b) = 0 \quad \frac{\partial S}{\partial b} = \sum_{i=1}^n (2x_i^2 b - 2x_i y_{real} + 2x_i^3 a) = 0$$

By setting simultaneous equations, the calculation formula for  $a$  and  $b$  can be obtained:

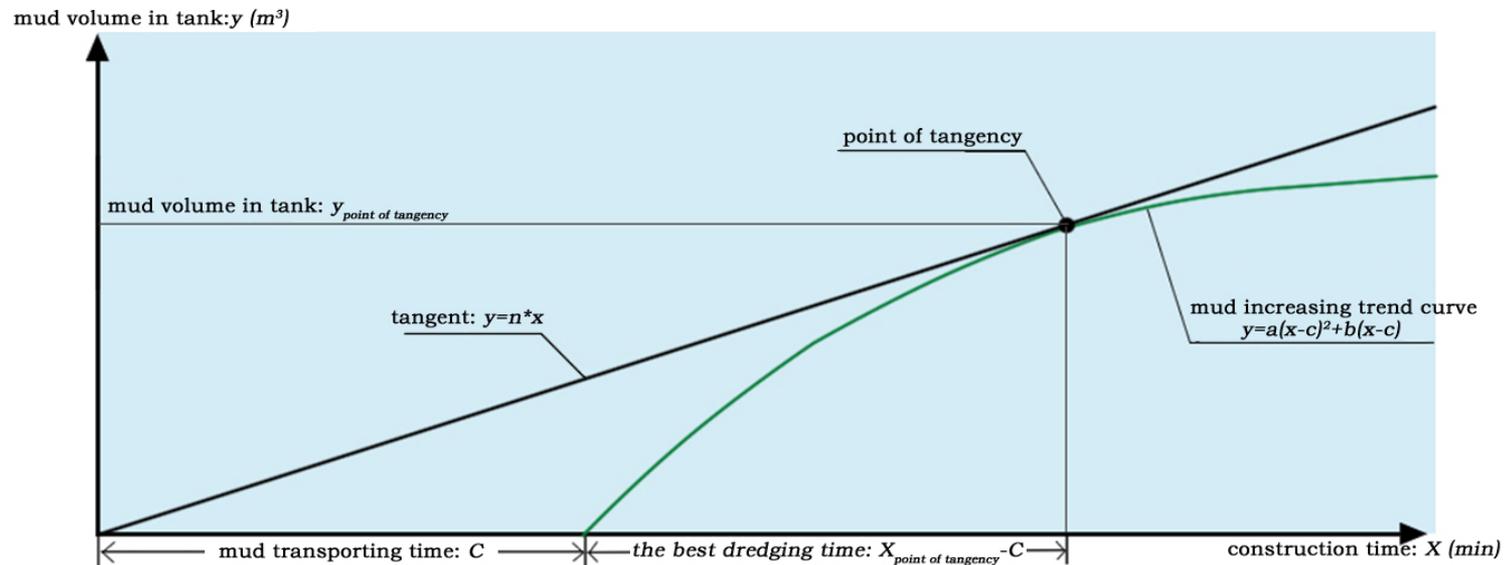
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$$a = \frac{\sum x_i^2 \times \sum x_i^2 y_{real} - \sum x_i^3 \times \sum x_i y_{real}}{\sum x_i^2 \times \sum x_i^4 - \sum x_i^3 \times \sum x_i^3} \quad b = \frac{\sum x_i y_{real} - \sum x_i^3 a}{\sum x_i^2}$$

When the value of  $a$  and  $b$  is calculated out, the curve fitting the increasing trend for mud in hopper can be obtained.

## 3、Ideal production efficiency calculation

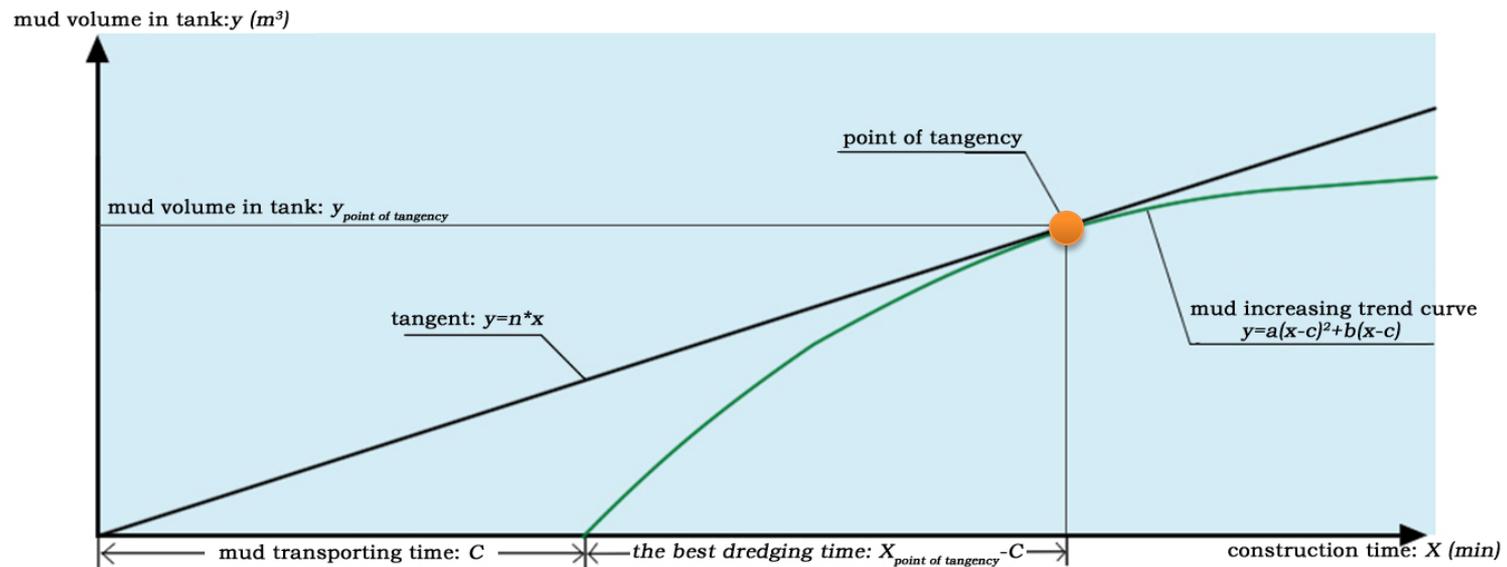
In order to achieve the best production efficiency, the ship should control the dredging time based on the mud volume in hopper and the sailing time. In here, we fit the increasing curve of mud in hopper and use the derivative algorithm to find out the ideal dredging time.



The principle of the derivative algorithm for dredging time calculation

## 3、Ideal production efficiency calculation

The key point of the derivative algorithm is to find out the tangent point on the mud loading curve with the line which crosses the zero point.



The principle of the derivative algorithm for dredging time calculation

## 3、 Ideal production efficiency calculation

### The calculation principle

**Mud loading equation:**  $y = a \times (x - c)^2 + b \times (x - c)$

**Tangent equation:**  $y = n \times x$

$a$  and  $b$  are coefficients

$c$  is the time of sailing time (10s);

$x$  is dredging time of the current ship load(10s);

$n$  is the slope of the tangent,

$$n = \frac{dy}{dx} = 2a(x - c) + b$$

## 3、Ideal production efficiency calculation

By setting simultaneous equations of above formulas, the tangent point can be obtained.

$$x_{\text{tangentpoint}} = -\frac{\sqrt{a^2 c^2 - abc}}{a}$$

Use  $x_{\text{tangentpoint}}$  to minus sailing time  $c$ , the ideal dredging time can be obtained.

$$x_{\text{ideal}} = x_{\text{tangentpoint}} - c$$

The ideal production efficiency is:

$$p_{\text{ideal}} = \frac{ax_{\text{ideal}}^2 + bx_{\text{ideal}}}{x_{\text{tangentpoint}}} = \frac{a(x_{\text{tangentpoint}} - c)^2 + b(x_{\text{tangentpoint}} - c)}{x_{\text{tangentpoint}}}$$

## 4、Fuel consumption calculation per 10000 m<sup>3</sup> of mud removal

- During production, the fuel consumption is made up of sailing and dredging fuel consumption and is mainly calculated based on instantaneous diesel engine power.

sailing and mud discharging fuel consumption (t): 
$$y_{sailing} = \sum_{n=0}^c \frac{194.3 \times 10 \times (w_{left} + w_{right})}{10^6}$$

dredging and shipping fuel consumption (t): 
$$y_{dredging} = \sum_{n=c}^{x-c} \frac{194.3 \times 10 \times (w_{left} + w_{right})}{10^6}$$

fuel consumption per 10000 m<sup>3</sup> mud (t/10000m<sup>3</sup>): 
$$T_{fuelconsumption} = \frac{y_{sailing} + y_{dredging}}{a(x - c)^2 + b(x - c)} \times 10000$$

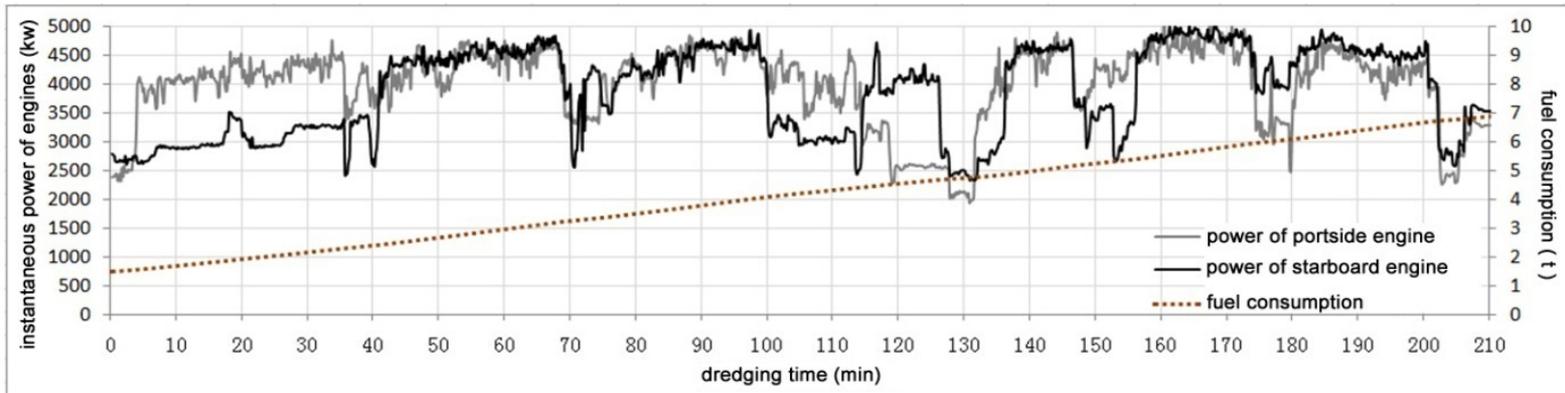
194.3 is the instantaneous fuel consumption of the diesel engines (g/kw\*h);

$c$  is the time of sailing (10s);

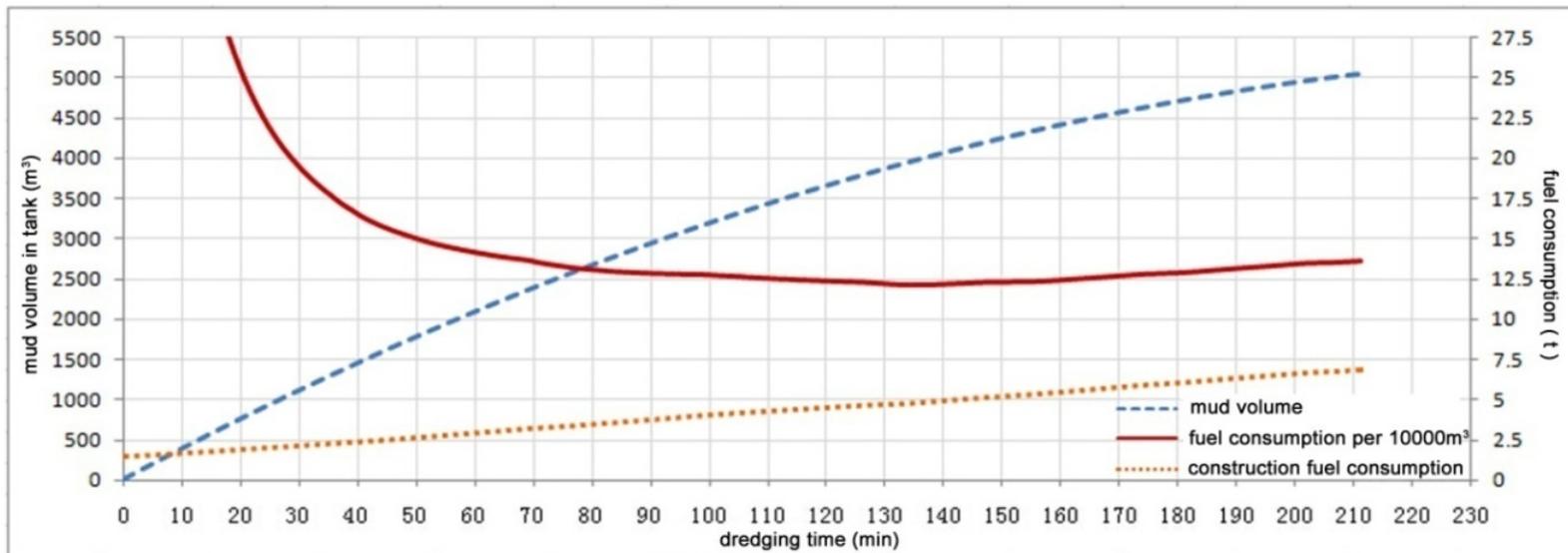
$x$  is dredging time of the current ship (10s);

$w_{left}$  and  $w_{right}$  are respectively the instantaneous power of portside and starboard engines (kw).

## 4、Fuel consumption calculation per 10000 m<sup>3</sup> of mud removal

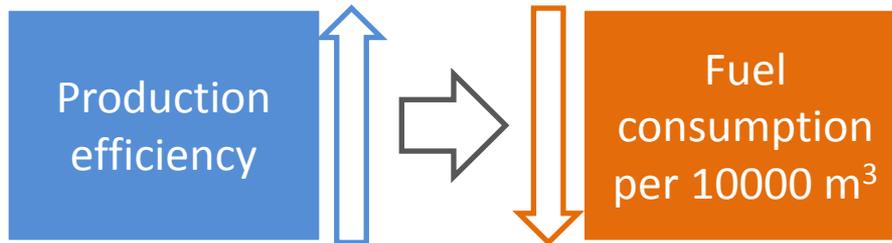


Increasing trend of construction fuel consumption

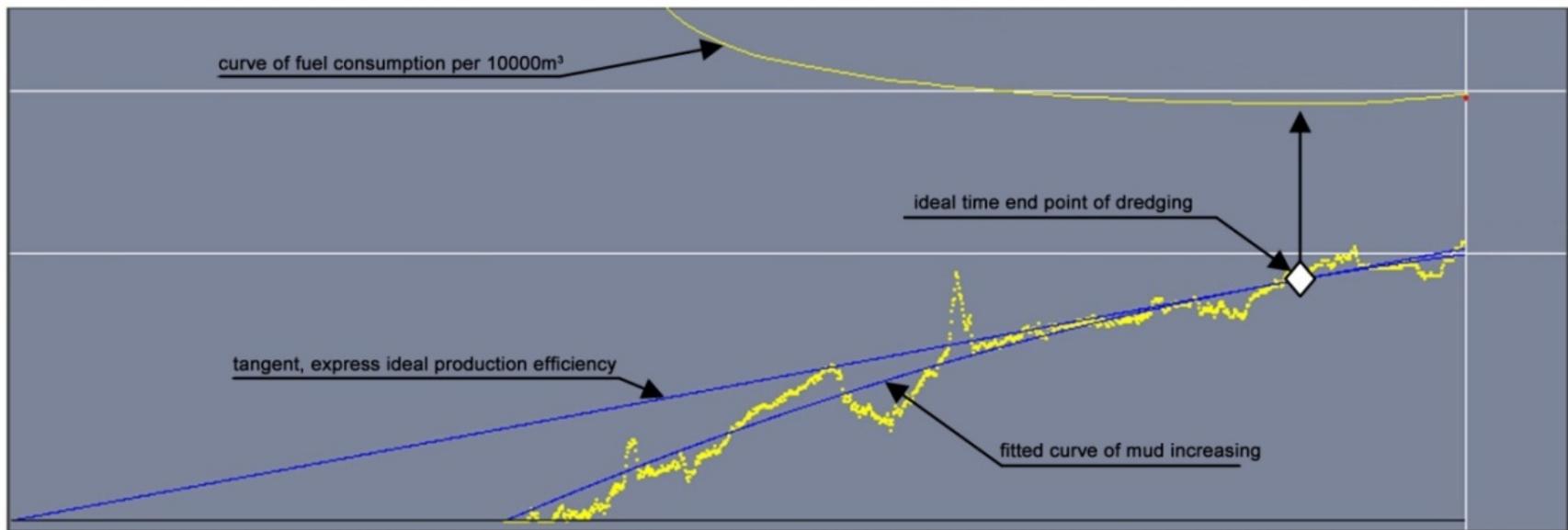


Changing trend of fuel consumption per 10000m<sup>3</sup> of mud production

## 5、 Reference method for production efficiency and fuel consumption per 10000m<sup>3</sup>



During the dredging process, fuel consumption per 10000m<sup>3</sup> decreases with the increasing of mud volume in the hopper.



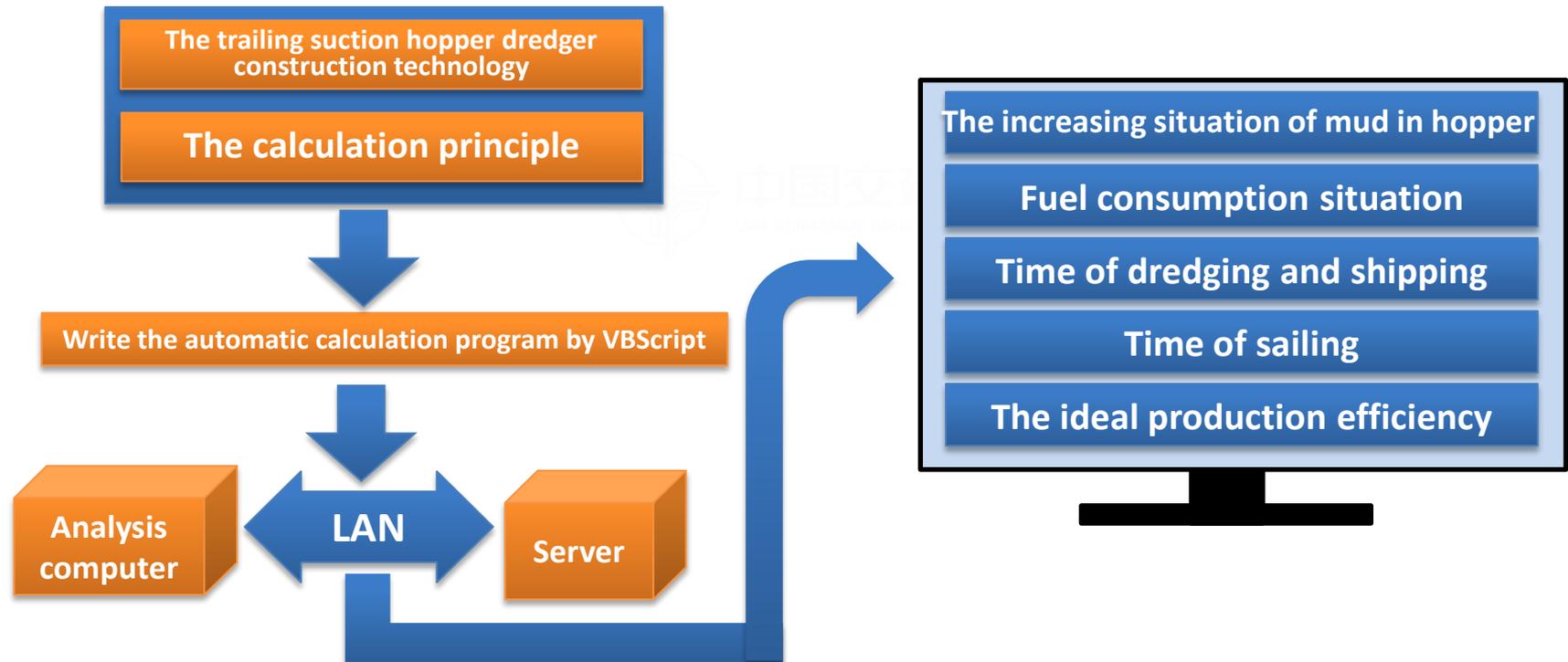
When the fuel consumption is the lowest, the production efficiency is the best and the ship should stop loading and start transporting at this moment when the economy is the best.

## 5、Reference method for production efficiency and fuel consumption per 10000m<sup>3</sup>

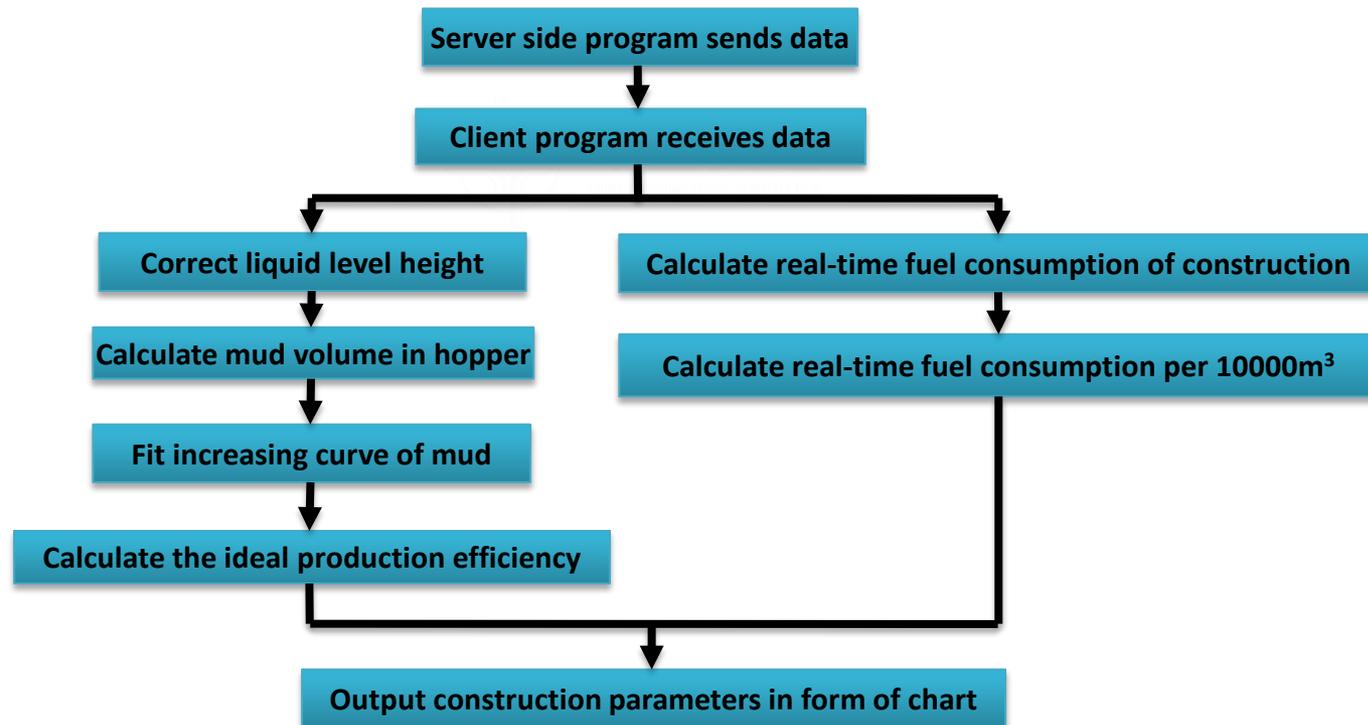
During actual construction, the operators should pay attention to the following points:

(1) When the dredging vessel is operating at the optimal point, the production efficiency will be the highest and the fuel consumption will be the lowest. In this stage, the production efficiency will increase gradually and then keep horizontal. And the curve of fuel consumption will decline gradually and keep horizontal.

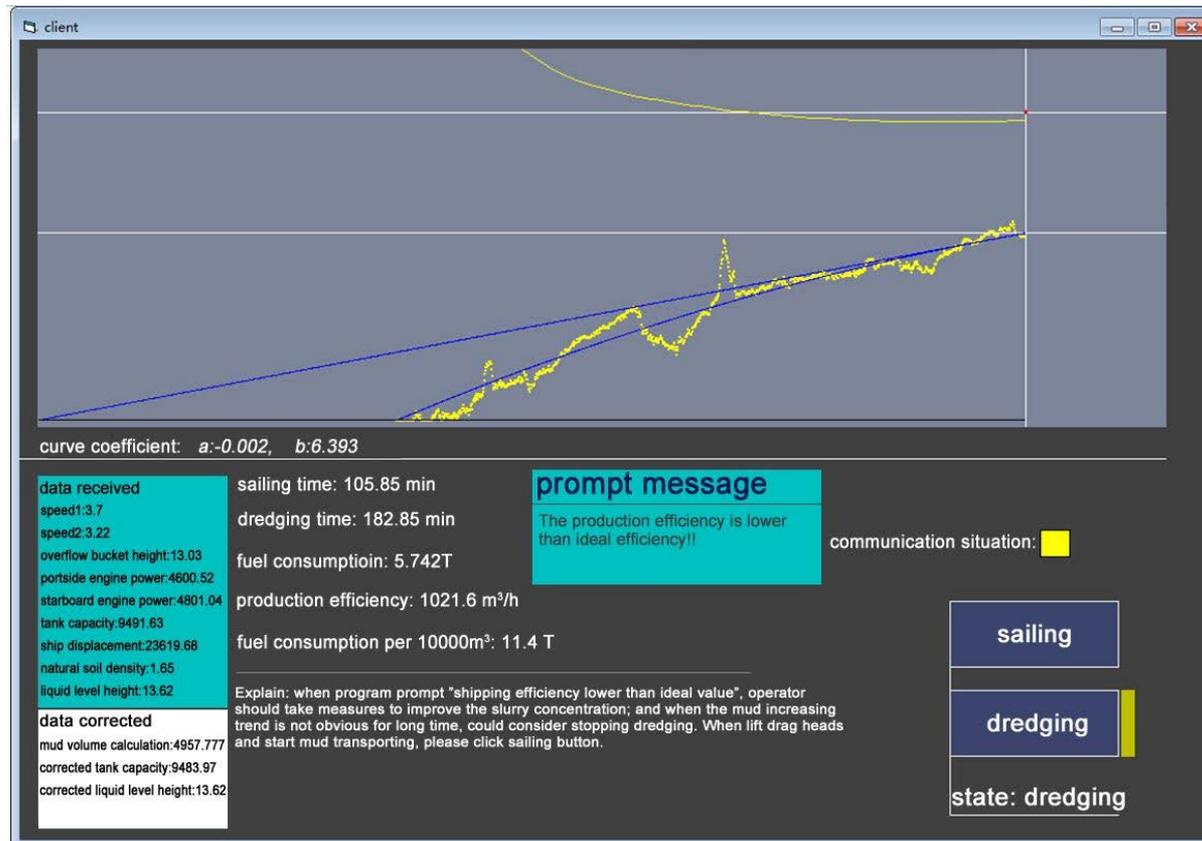
- During project construction, if calculate the ideal production efficiency by hand, the calculation process is complicated and the result is not visual. In order to calculate automatically, we need a calculation program to do this work accurately and quickly.



- This program is divided into two parts, the server side program and the client program. The server side program runs in the server and gathers construction data, and it sends data to the client program through LAN. The client program monitors communication ports in real time, when it receives the data, it will corrects, analyzes, calculates and displays the results visually.



## ■ The working windows of the server side program and the client program.



Working window of the client program

■ **The construction data gathered by calculation program are:**

Slurry speed of portside pump

Slurry speed of starboard pump

Liquid level height in hopper

Overflow weir height

Mud hopper capacity

Ship displacement

Portside , starboard engine power

Natural soil density

## ■ Key technology

Use **winsock** control and **scktcP** communication protocol to transfer data

The server side program sends data and the client program monitors this over the whole course of events which makes the data transmission happen in real time and be stable.

Proposed for the first time:

Correcting principle for the hopper capacity

Fitting increasing curve of mud in hopper  
with the least square method

Calculating ideal production efficiency with  
derivative algorithm

Calculating fuel consumption based on  
instantaneous diesel engine power

This program records construction parameters and do calculation every 10s which can balance the processor pressure and give accurate calculation results.

Today I introduce the automatic calculation principle for production efficiency and fuel consumption per 10000m<sup>3</sup> of mud and other key project construction parameters. And also introduce the key technology and running process of the automatic calculation program. I hope to share my experience to colleagues around the world to promote the level of the trailing suction hopper dredger's construction technology and to establish a wonderful world.





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