

# AN INNOVATIVE OOZE DREDGING FOR ENVIRONMENTAL PRESERVATION

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**Abstract:** Up to now, ooze dredging has presented many problems: because the mud content ratio is low and has a wide variation and the positioning of the dredger and operation of the ladder is done by hand, ooze dredging has been of poor precision, with the dredging being either too deep or too shallow, and the operating efficiency has been low because the actual mud pumping up time amounts to only a small part of the dredging time, and many workers are required. By dealing with these technical problems, developing and improving the dredging equipment, and developing a dredging automatic control algorithm to greatly automate the operations, the Automated (Robot) dredger 『Kasumizaurusu』 has been completed.

**Keywords:** Ooze dredging, Kasumigaura, Improvements for dredging automation Automation for dredging work managing system

## 1. Introduction

The lake Kasumigaura located in the south east part of Ibaragi prefecture, and the second largest lake in Japan of 220 square km lake area and 2,150 square km catchments area, is a precious jewel for habitants living around the lake as the water supply source for agriculture, industries, and drinking water, as well as for fishing water and for pleasure activities.

The water of the lake is very susceptible to be polluted or contaminated because of more than 50 rivers larger or smaller flowing to the lake and bringing contaminating materials to the lake water, and because of lack of lake depth, about 4 meters in average and about 7.3 meters at the deepest spot. Pollution of the lake has worsened in 1970s and later due to the increase in the population, and growth in the economies and other social activities in the area surrounding the lake, thereby causing eutrophication in the lake water, thus it has been seriously affecting the water utilization and the conservation of the environmental conditions of the lake.

The pollution of the lake is thought to worsen for an external cause and an internal cause to the lake. The external cause is sewage brought by streams in the catchments area, and the internal cause is materials liquating out from the sludge

accumulated on the bottom of the lake.

As the measure to clean the lake water by disposing eutrophication sludge on the lake bottom, dredging work started in 1975, and the greater scale dredging work started in 1992 aiming to accelerate the water cleaning plan.

The project for the water cleaning was planned to dredge 30 cm thick sludge layer on the lake bottom as the final target by 2010, which is to dispose sludge equivalent to one fifth of the total estimated sludge volume in the lake (40 million cubic meters in total), or 8 million cubic meters.

The dredger “Kasumizaurus” was built in 1994 as a highly robotized dredger to carry out the main role in this great scale dredging project. The dredger has been employed for dredging work every year for eleven years since its completion being implemented with various improvements to achieve higher dredging performance, higher sludge density dredging, higher positioning accuracy, and for manpower saving reflecting the results and experiences having been obtained in the actual operation.

The paper presents major improvements which we have so far made to the dredger.

## 2. Special requirements to dredging work for the lake Kasumigaura

The sludge accumulated on the lake bottom, the internal source of the lake pollution is phosphorus and nitrogen rich ultra soft sludge containing 200 to 400 % water. Therefore the dredging has to be carried out not to disperse the sludge in the lake water. Further for disposal of the sludge on the land surrounding the lake after drying outdoor natural drying procedures, the dredging has to be done with high sludge density mode.

### (1) Introducing of high performance dredging system for speedier dredging work

The high performance dredging systems were introduced for speedier dredging work. Mechanisms of a spud-carriage and a sludge collector with a rotating stand are installed for that purpose. Further the automation system realized continuous stable dredging operations, thereby reduced indirect working time including “no load operation time”, resulting higher working performance in terms of operation time ratio and work efficiency.

### (2) Sludge collecting device with rotating bucket for high sludge density dredging and less sludge dispersion

The sludge collecting device consist of a bucket containing a rotating drum fitted with sliding cutter knives for cutting and collecting sludge, a screw conveyor to lift the collected sludge, and a sludge suction pump to suck and pump out the sludge. The depth of the sliding cutter knives was designed to be equal to the depth of the sludge layer accumulated on the bottom of the lake so that the sludge collecting device can maintain higher sludge density lessening sucked water.

Rotating speed of the rotating drum and the swinging operation are automatically synchronized for smooth cutting and collecting of sludge without causing disturbance in the sludge layer, and preventing dispersion of the sludge in the lake water.

### (3) Manpower saving and robotic operation by automation system

Automation systems were introduced to achieve higher operation efficiency, and manpower saving and robotics. The systems realized remarkable improvements in efficiency of dredging work, for dredging position accuracy, for manpower

saving and for environment-friendly dredging work.

## 3. Outline of the automation system

The Fig.1 Outline for dredging operations with automatic dredging system

### 3-1 Automatic control

The programs of the computer system for automatic controls are of integration of independent programs for respective functions of dredging devices. The respective dredging devices are operable in automatic mode or manual mode independently to other devices and in any combinations. Operators are allowed to interrupt automatic operations and to take over for manual operation at any moments as required to maintain efficient operations.

Respective automatic control functions are as following.

#### (1) Automatic control for swing operation

The angular speed of the swing operation is automatically controlled as to keep the preset speed. The swing speed is automatically reduces when reaching the preset swing limit, is subject to acceleration control at starting of the swing operation.

#### (2) Automatic control for ladder winch

The ladder winch is automatically controlled to keep dredging depth as the preset target dredging depth. The ladder winch is automatically started for lowering or lifting responding to the command for dredging start or stop.

#### (3) Automatic control for sludge collecting device including controls for the sludge suction pump, the rotary bucket, the screw conveyor and the rotary stand

The rotating speed of the rotary bucket and the speed of the screw conveyor are automatically controlled as synchronized with the swing speed.

The sludge suction pump is automatically controlled for its flow rate as synchronized with rotating speed of the rotary bucket.

The sludge suction pump is also automatically controlled to limit its flow rate to be lower than that of the sludge transfer pump when the level of the sludge storage tank reaches the upper limit.

#### (4) Automatic control for sludge transfer pump

The sludge transfer pump is automatically started and

controlled of its speed responding to the level of the sludge storage tank.

The sludge transfer pump will be kept running by circulating sludge flow with the circulating valve opened automatically at excessively high pressure in the sludge transfer line, which may occur upon shutting of the transfer line or for other reasons during operation.

#### (5) Automatic barge shifting control

The barge is automatically traveled forward as per the preset distance using the spud carriage when the swing is at the end limit. Position of the sludge collecting device in swing direction is also automatically controlled.

#### (6) Automatic control for spud

The spud changing operation is automatically done as the spuds being lifted or set when the spud carriage reaches the end limit and the swing motion is stopped by the automatic swing control at the center position.

### 3-2 Operation monitoring

The operation monitoring system consists of the subsystems for dredging monitoring, barge position monitoring, and work managing monitoring. Three sets of LCD (Liquid crystal display) are provided for display of the information and data.

The functions of the operation monitoring system are as following.

#### (1) Dredging monitoring

Status of the spuds, position of the sludge collecting device, setting values of the various parameters and alarms are displayed on the display device.

The Fig.3 indicates display for the spud status and the Fig. 4 indicates position display for the sludge collecting device.

#### (2) Barge monitoring

The displays are given for barge positions and the parameter setting.

The Fig. 5 indicates the display of traces for the movements of the sludge collecting device. The said display also represents the barge position.

#### (3) Work managing monitoring

The work managing monitoring includes displays for work progress data input, and work managing documentation as well

as printing.

The Fig.6 Display for dredging area and the Fig.7 Display for bottom depth measurement records (before and after dredging work)

## 4. Improvements for dredging automation

### 4-1 Implementation of RTK-GPS (Real Time Kinematic - Global Positioning System) barge positioning system

The conventional method for the initial barge position setting was the triangular surveying method, with which initial spud position was set based on three known land marks, after that further movements and positions of the barge were taken by integration of displacements measured as strokes of the spud carriage and measured by a gyro compass. However the barge positions measured with the conventional method caused large errors integrated for fragments of errors due to lateral movements of spuds, errors in strokes of the spud carriage and other reasons. The measurement errors drifted positions of the barge resulting uncut of the sludge layer on the lake bottom.

In order to correct the drift of positions of the barge, persons were always placed on the land to do frequent position corrections which required stopping the dredging operation accordingly. Therefore the position correction was time consuming work resulting less efficient dredging. Since position measurements were also required in changing the dredging locations, the similar time losses were also occurred.

The RTK-GPS barge positioning system realized accurate real time position measurements of the barge. Therefore position corrections of the barge became available during spud setting operation so as to keep the barge in accurate position as not causing an uncut of the lake bottom in the new dredging paths. The system was also able to eliminate loss time in changing dredging locations, because the system provides position measurements even during traveling of the barge, thus loss time for the change of dredging locations were shortened and manpower on the land for barge position measurement was saved.

### 4-2 Adoption of backward dredging

Since the conventional dredgers were designed for dredging in forward direction only, the barge had to be relocated to initial positions with the swing anchors being retrieved and the barge being traveled long distance to backward for every 400 to 500 meters continuous dredging in the forward direction.

Particularly in the case of the subject dredger connected with a floater for sludge disposal pipes, changes of dredging locations would have required full one day, if the forward dredging only had been adopted.

Thanks to adoption of the two direction dredging mode (dredging backward in addition to the conventional forward dredging mode), only 40 meters lateral shift of the barge is required to adjust the barge positions for new dredging area without relocation of the swing anchors or the floater for the sludge pipes. As the result changing to new dredging area was tremendously shortened to about one hour. The Fig. 2 indicates procedures for dredging operation with the two direction dredging mode.

#### 4-3 Adoption of continuous dredging function

In the conventional dredgers, one complete operation cycle between spud settings comprised seven steps as indicated in the Fig. 1 requiring manual position correcting operations of the barge in respect of the targeted dredging lines during spud setting operations.

With RTK-GPS barge positioning system introduced to the subject barge which realized real time position measurements, the deflections of barge positions in respect of the target dredging line were automatically detected even during spud setting operations. As the results the continuous dredging operations were realized. Accordingly highly efficient dredging operations and manpower saving were achieved by eliminating manual deflection correction of the barge in spud setting operations.

#### 4-4 Automation for dredging work managing system

The conventional way for managing dredging depth was based on the manual calculation using the draft data of the barge and original survey data for bottom depth of the lake having been captured before the dredging work, and then the ladder was lowered to the depth decided as mentioned before.

If depths of the bottom varied in the swinging range (about 40 meters), the depth of the ladder was adjusted by controlling the ladder winch manually as necessary.

Depth data to be submitted to the administration of the project after dredging work are verified comparing with the actual depth data surveyed after the dredging.

In the automatic dredging work managing system, the draft

data of the barge are captured by the RTK-GPS system on the real time basis. The draft data provided by RTK-GPS system and the bottom depth survey data before dredging work in digital form are input to the automatic dredging work managing system, and then the system will automatically calculate and output the data required for setting dredging course and dredging depth, and for other dredging operations.

The automatic dredging work managing system also controls the ladder winch on real time basis so as to keep target depths of the sludge collecting device.

A dredging depth measuring device is provided to capture actual bottom depth at the areas where dredging have been carried out, as such are used for making throughput records to be submitted at the completion of the work.

The work progress reports are automatically produced. The reports contain dredging area in X-Y-Z coordination, original bottom depths measured previous to the commencement of the work, depth data of the sludge collecting device and bottom depth after the dredging work completed.

## 5. Conclusion

The dredger “Kasumizaurus” has been continuously improved for economical dredging work, higher operating efficiency and manpower saving making good use of experiences and data obtained in the actual operation having continued for 11 years.

The automatic dredging work managing system has not yet achieved such target as to take over for the conventional managing procedure though, we will continue to try further to complete the system using accumulated data relating with dredging accuracy, operating conditions through actual operations.

The lake Kasumigaura has great influence to the life of the people in the lake area. So we will continue to try for improvement of the dredging work hoping that the dredger “Kasumizaurus” will accomplish expected roles for recovery of environmental conditions of the lake area and for better life of the people living in the surrounding area of the lake.

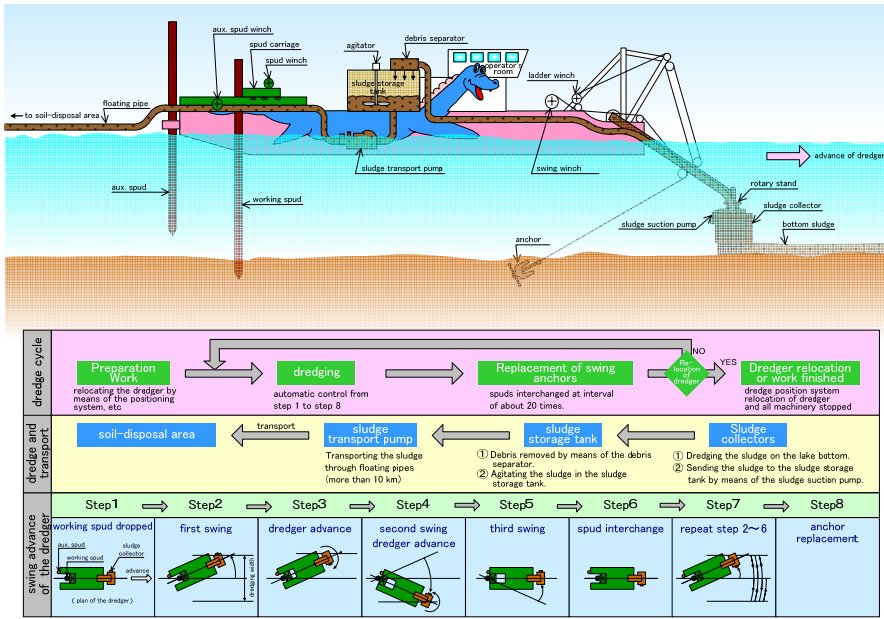


Fig.1 Outline for dredging operations with automatic dredging system

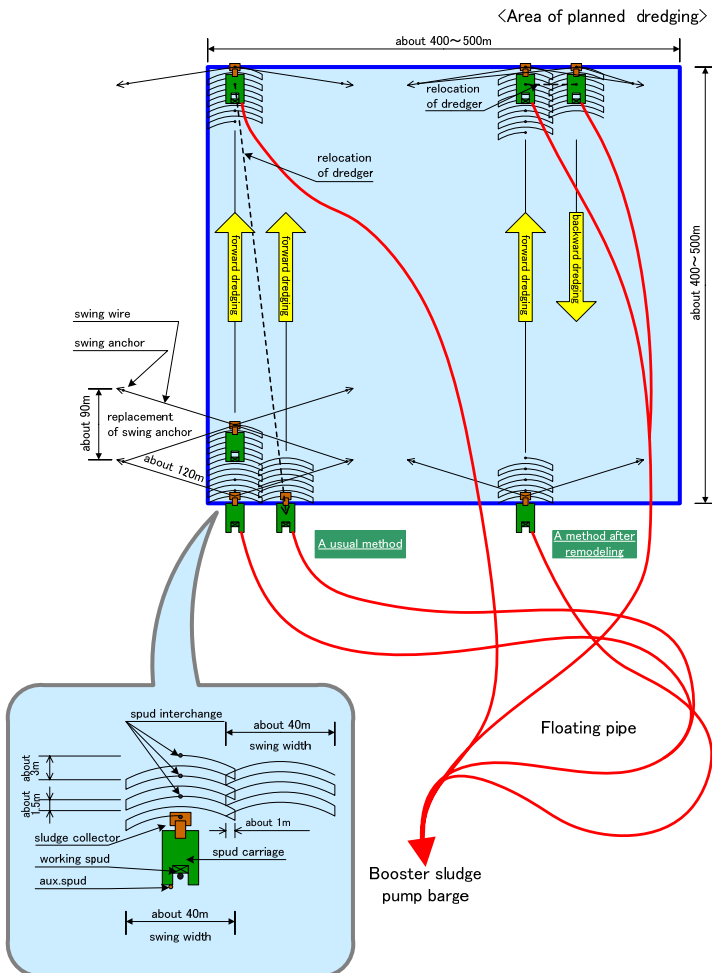


Fig.2 Dredging work procedures with backward dredging

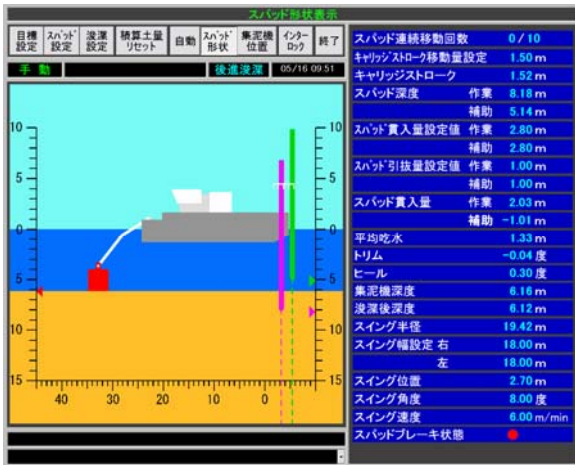


Fig.3 Display for spud status

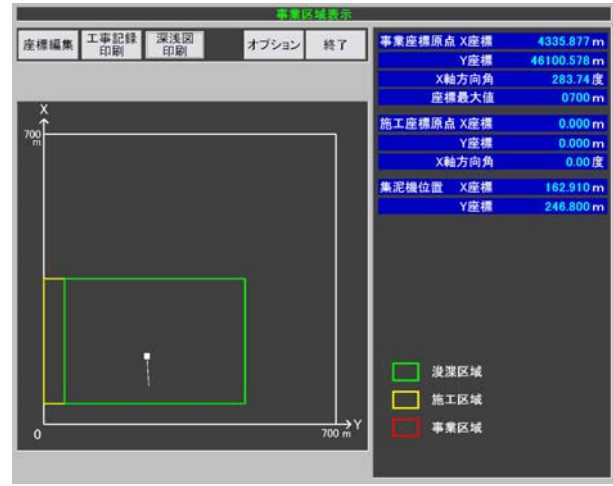


Fig.6 Display for dredging area

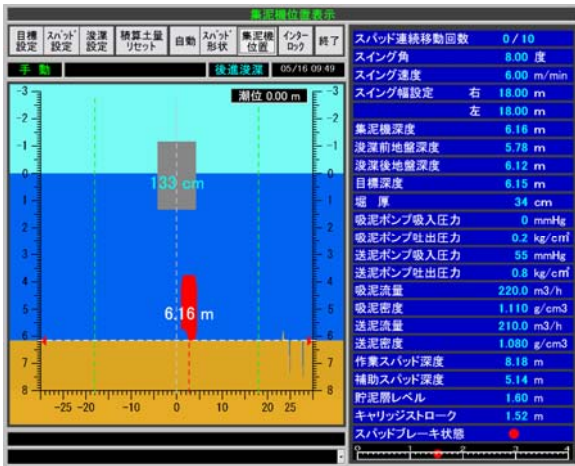


Fig. 4 Display for positions of the sludge collecting device

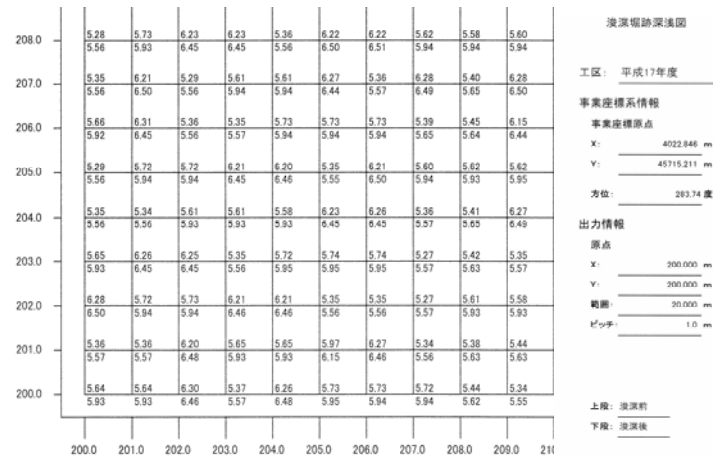


Fig.7 Display for bottom depth measurement records (before and after dredging work)

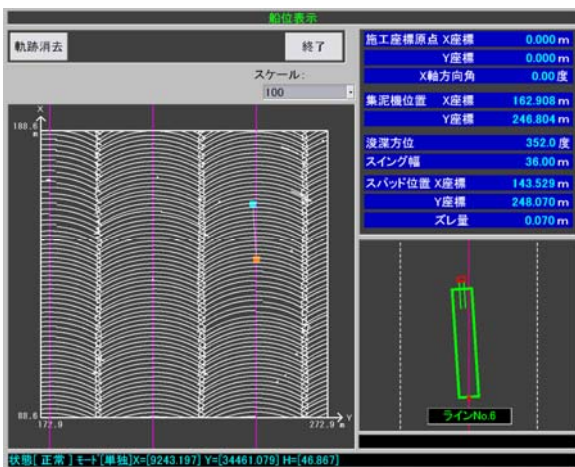


Fig. 5 Display for traces of the barge