

Automatic Extension Robot for Slurry Transport Pipes

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ABSTRACT

In promoting effective utilization of underground space now attracting attention, the shield method has gained greater significance, and construction of the tunnel is expected to speed up, because the services of the underground facilities are required to start earlier than before. On the other hand, one of the problems in the entire Japanese construction industry has been aging of workers and shortage of skilled labor, which has created greater demand for labor-saving construction methods.

With the above conditions in the background, Kumagai Gumi Co., Ltd. has been developing the methods which will speed up the work steps of the shield method and facilitate its automatization. As part of such effort, we have developed an automatic extension robot for slurry transport pipes used in a facility transporting excavated soil and fluid in construction work by the slurry shield method.

This report introduces the configuration of the robot, its functions, and one of its application examples in a large-bore (of a diameter of 10 m) slurry shield.

1. INTRODUCTION

In the slurry shield method to which this robot is applied, slurry is sent to the front of the shield machine to pressurize the cutting face for its stabilization, while the debris excavated and mixed with slurry is discharged to the slurry treating plant located outside of the shaft. Here, important roles are played by the slurry feed pipes sending the slurry to the front of the shield machine and the muck discharge pipes discharging excavated debris to the outside of the shaft.

These slurry transport pipes are required to be extended as the excavation work develops. Generally, this extension work is repeated each time the unit completes excavation for the length of a pipe (about 6 m) until the tunnel goes through in the back of the carriage in the shaft following the shield machine. The robot is an automatic device which enables pipe extension work to be achieved with less labor, higher safety and reduced work hours.

2. PRESENT CONDITON OF SLURRY PIPE EXTENSION WORK

Fig. 1 shows the procedures of the conventional slurry pipe extension work. First, measures are taken to prevent slurry runoff, metal seams (referred to as victaulic joints) are removed, and secondly the flexible hoses of the extention equipment are wound shorter to ensure space enough to extend the pipings. Then, several workers lift

the pipe conveyed from outside the shaft, transfer it to the secured space, then install it there. Next, they lift up the ends of the existing and newly installed pipes, align them with each other, and fasten the victaulic joints. These steps involve handling of very heavy material on an unstable ground, requiring extremely strenuous work.

3. NECESSITY OF INTRODUCTION OF THE ROBOT

Not only for higher safety and elimination of the strain of the labor but also to cope with the tendency of the shield-driven tunnels to become greater in diameter and length and to reflect the development of automatization and practical application of robots, the following issues have become necessities concerning the slurry pipe extension work:

1) Greater diameter of a shield-driven tunnel

The greater the diameter of a slurry pipe becomes, the weight of pipes to be handled increases, resulting in difficult work beyond the limit of manual labor of human resources. Therefore, it is urgently required to introduce robots for safety and labor saving considerations.

2) Higher speed of segment assembly work

Since a series of steps for extension work are carried out concurrently with segment assembly work as soon as the shield tunnelling has completely finished the predetermined distance, it is required to perform extension work within the time spent for assembling segments in order to maintain an optimal construction cycle without any loss time.

As the introduction of robots develops in assembling segments in future to achieve higher speed of assembly, it will be even more greatly required to reduce time for extending pipes by using robots in order to maintain the construction cycle.

3) Lengthening of the tunnel

Generally speaking, lengthening of the tunnel increases the number of repeated extensions as well as the operation cycles of the battery locomotive. This has brought about a greater necessity of reduction in the pipe supply cycle by storing pipes at the extension spot and other rationalization measures to improve construction efficiency.

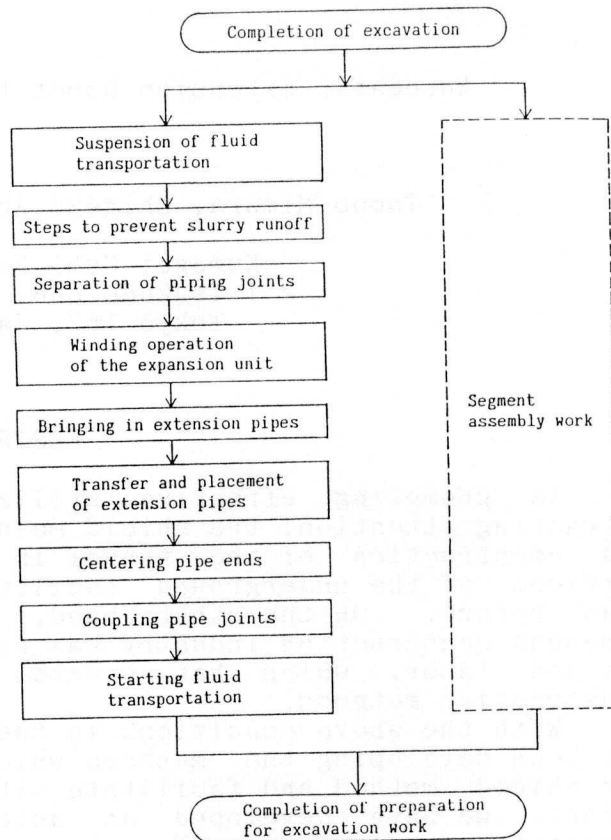


Fig. 1 Procedures for the conventional extension work for slurry transport pipes

4. OUTLINED DESCRIPTION OF THE ROBOT

4.1 Features of the robot

The robot has the following features:

- (1) This self-propelled robot travels to the specified extension spot on the track in the shaft to grip, convey, and position the pipes, then returns to the home position after coupling the metal seams, all of which are done in automatic operation.
- (2) It enables handling of pipes of greater diameters and weight which cannot be easily handled manually.
- (3) As all the handling works of heavy pipes are automatized, remarkably high safety level is achieved.
- (4) Compared with the conventional manual work, the length of time used for expansion work can be reduced and labor can be saved.
- (5) It is possible to provide the robot with a stock of pipes required for extension work, and
- (6) It provides easier operation with most of the operation being performed automatically.

4.2 Configuration of the robot

The overview of the robot is shown in Fig. 2. The robot is composed of the following components:

(1) Carriage

The carriage is of a gantry type driven by an electric motor with a brake. This carriage is self-propelled and travels to the specified pipe extension spot, running on the track installed in the shaft.

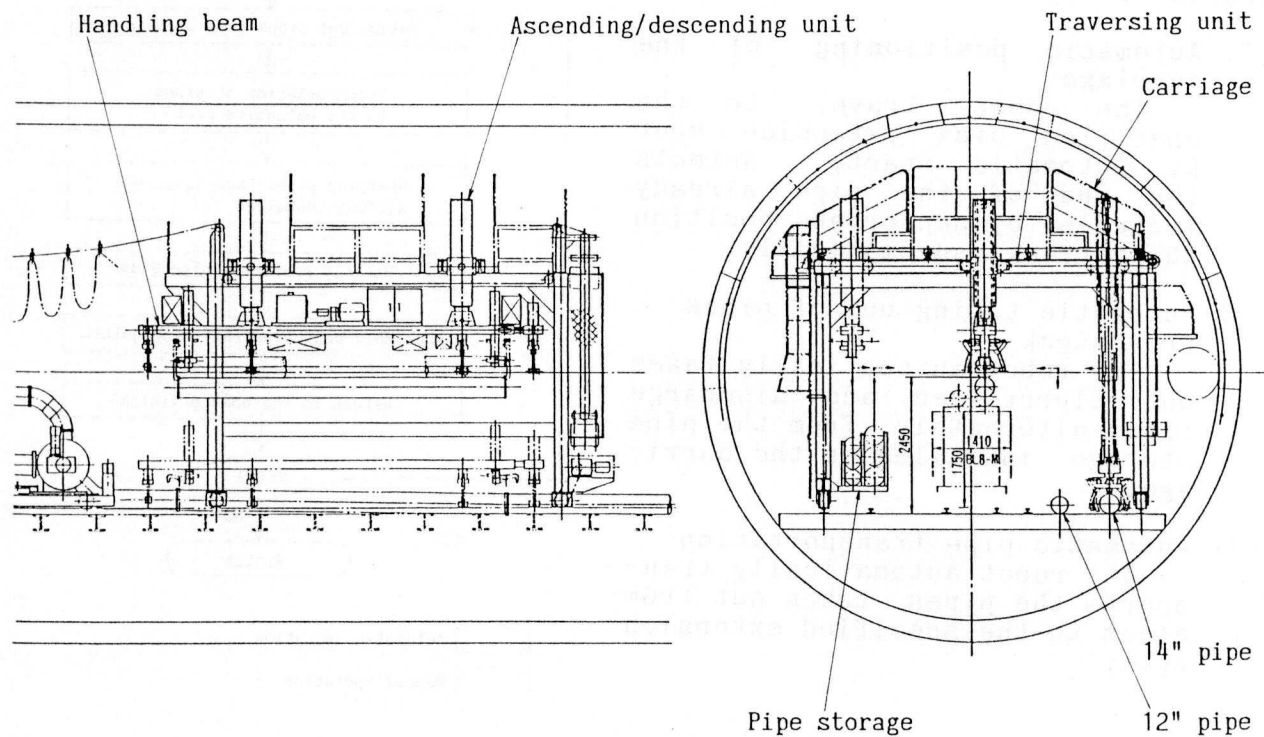


Fig. 2 Overview of the robot

Also, this carriage is provided with a temporary storage for pipes used for extension work.

- (2) Handling beam
The handling beam is provided with four types of hands to grip pipes according to the respective uses at the times such as taking out pipes from stock, transporting, positioning, and performing ascend/descend or traverse motions.
- (3) Ascending/descending unit
This unit has a built-in two-step hydraulic jack which expands and compresses to ascend and descend the handling beam. The frame has a guide-box structure to prevent vibration of the load in the traverse motions as well as to enable the pipes to be easily aligned.
- (4) Traversing unit
This unit performs traverse motions of the handling beam on the rail at the top of the carriage, driven by hydraulic motor.
- (5) Control unit
This unit has comprehensive control over each of the above units and operates them in the automatic or manual mode or by remote control.

4.3 Functions of the robot

Fig. 3 shows the flow of fundamental actions of the robot. In order to perform operations shown in Fig. 3, the following functions are provided.

- (1) Automatic positioning of the carriage
The robot travel to the specified pipe extension spot by Automatic Start, detects the end of the pipe already installed by sensor, and position the carriage automatically.
- (2) Automatic taking out of pipes from stock
The robot automatically takes out slurry feed and discharge pipes alternately from the pipe storage installed on the carriage.
- (3) Automatic pipe transportation
The robot automatically transports the pipes taken out from stock to the specified extension spot.

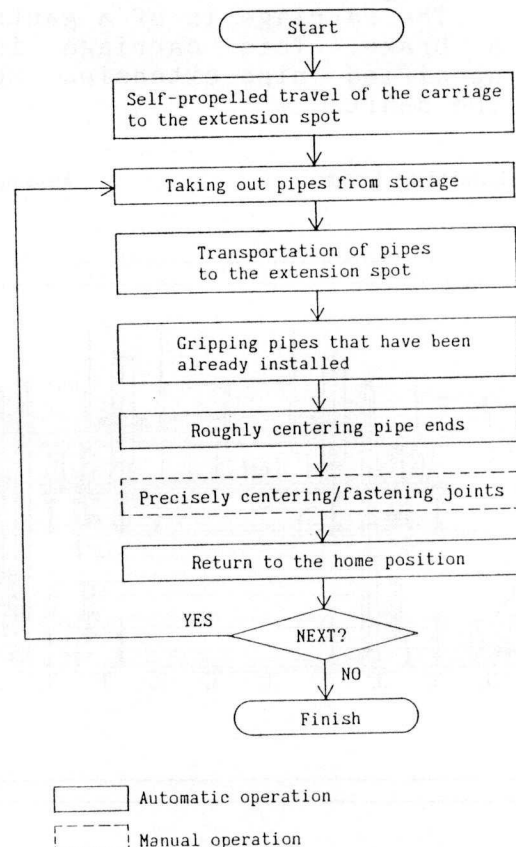


Fig. 3 Flow of fundamental actions

(4) Alignment of pipes-laying

The robot, holding the pipes already laid, automatically aligns roughly them with the new pipes.

(5) Return to the home position

This function makes the handling beam retreat to a safe position after coupling pipe joints.

Furthermore, the loading of pipes from the battery locomotive to the pipe storage can be easily performed by radio-controlled one-man operation.

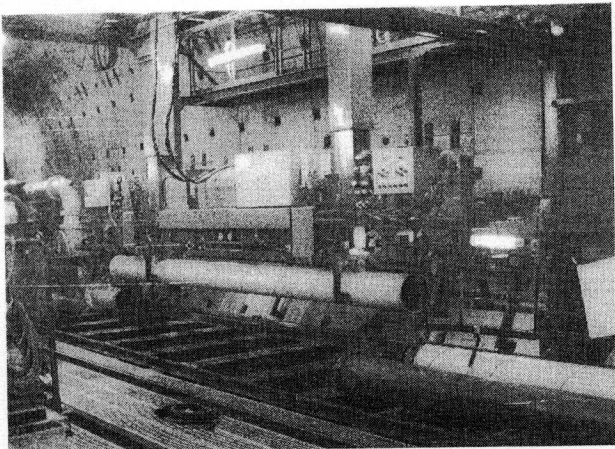


Photo 1 Automatic pipe transportation

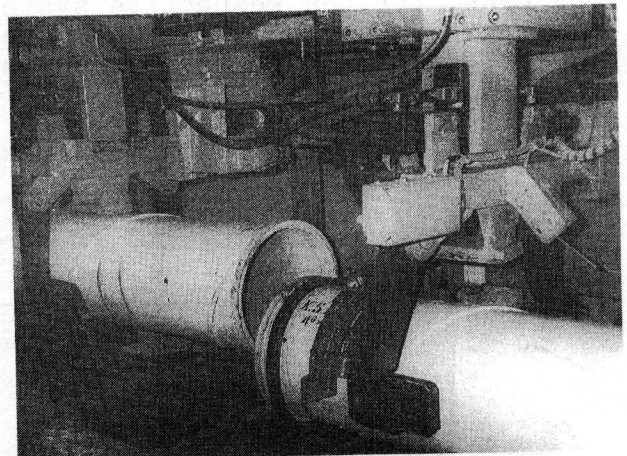


Photo 2 Alignment of pipes-laying

4.4 Safety devices:

This system is provided with the following safety devices:

- (1) A revolving lamp with a human body sensor that warns with artificial voice on detecting a worker coming close to the robot,
- (2) An area sensor that causes emergency stoppage when a worker enters the operation area of the handling beam during automatic operation,
- (3) Push-button switches and touch sensors at critical locations for emergency stoppage, and
- (4) A large-sized alarm lamp located in front and back of the carriage to indicate the current operation mode of the robot.

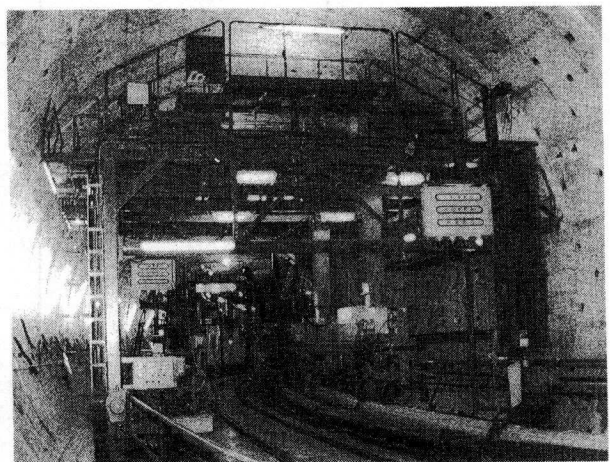


Photo 3 Overview

5. APPLICATION EXAMPLE IN A LARGE BORE (10 M) SLURRY SHIELD

This robot has been applied to the sewage construction work at the Kozukue-Chiwaka Storm Sewer in Kanagawa Prefecture since February last year, and is in operation now. This construction work involves a large-bore (of a diameter of 10 m) slurry shield, extending over a distance as long as 2600 m.

Table 1. shows the specifications of slurry transport pipes used in this construction. Both slurry feed and discharge pipes are configured in a single system respectively. The slurry feed pipes are 14B large-bore pipes, while the slurry discharge pipes are heavy-weight pipes weighing 300 kg each. One cycle of extension work covers 12 m for the slurry feed and discharge systems respectively, using 2 pipes, 6 m-long each, for the respective systems.

Table 2. shows the major specifications of the slurry transport pipe extension robot introduced in this construction work.

Table 1. Specifications of slurry transport pipes

Name	Pipe specification	Weight	Victaulic joint
Slurry feed pipes	Helical pipe 14"×2t ×6m	135 kg/pipe	W type
Slurry discharge pipes	STPG 12"×6.4t×6m	300 kg/pipe	S -1 type
Pipe extension in one cycle	Extension over 12m using 6m ×2 pipes for both slurry feed and discharge pipes		

Table 2. Principal specifications

Items	Description
Carriage Type Track gauge Travelling speed	Gantry type (self-propelled) 5750 mm 9 m/min.
Handling beam Ascending speed Descending speed Traversing speed	5 m/min. 5 m/min. 20 m/min.
Electric motor Travelling Power unit	2.2kw (4p)×2 11 kw (4p)×1 ; for handling beam 3.7kw (4p)×1 ; for traversing unit
Pipe specification	diameter ; 8"~ 14" length ; 6 m weight ; max.300kg
Pipe extension in one cycle	Extension over 12m using 6m ×2 pipes

5.1 Comparison with the conventional construction method

Fig. 4 shows comparison between the hours spent in this extension work and those in construction by the conventional method (using hoists). As the hours spent for preparatory and other work before and after extension work are of the same length, they are not mentioned here.

The introduction of this robot reduced time for extension work by 35% per 12 m-cycle. The ratio of the time for manual work in the total extension work was found to have been greatly reduced, with coupling of pipe joints being the only work to be manually performed. It has also been confirmed that the number of workers can be reduced by 50 - 60%, which means just two members including an operator are required for extension work. As for operational aspects of the robot, most of operation has been automated and requires no skilled labor, and it has been confirmed that any worker can easily operate the robot.

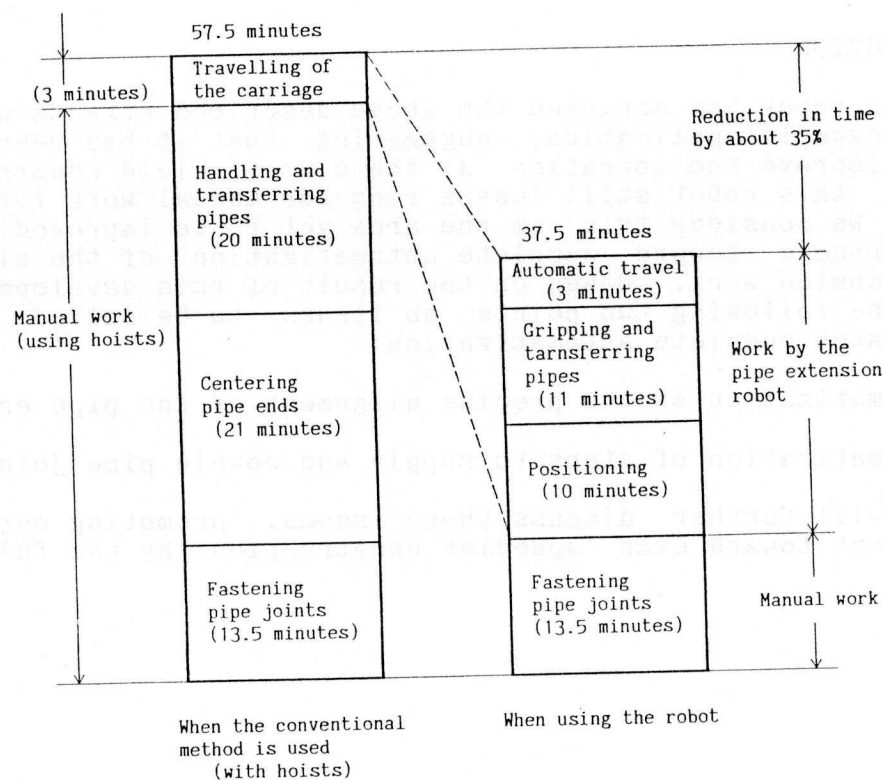


Fig. 4 Comparison of time required for extension work

5.2 The effect of introduction of the robot

The effect of introducing the slurry transport pipe extension robot can be summed up as follows.

(1) Reduction of work load

Work load has been reduced by automatization of the entire steps of handling heavy pipes manually performed in the conventional method.

- (2) Higher safety
Safety has been greatly improved due to total elimination of manual handling of heavy pipes on an unstable ground.
- (3) Labor saving
The number of personnel required for extension work has been reduced by 50 - 60%, achieving labor saving effect.
- (4) Improved construction cycle
The time required for extension work has been reduced by about 35% to be included within the time spent for segment assembly work, enabling the entire construction cycle to be improved.
- (5) Improvement of construction efficiency
The construction efficiency has been improved by storing pipes required for extension work on the robot.

6. CONCLUSION

This robot has achieved the above described effects when introduced in this example application, suggesting that it has been successfully helping improve the operation at the slurry shield construction site. However, this robot still leaves room for manual work for coupling pipe joints. We consider this as the area yet to be improved. We will step up the process toward complete automatization of the slurry transport pipe extension work. Based on the result of this development effort, we regard the following two points as issues to be solved before we can achieve such complete automatization:

- (1) Automatization of the precise alignment of the pipe ends, and
- (2) Automatization of steps to supply and couple pipe joints.

We will further discuss these issues, promoting our research and development toward even speedier construction by the fully automatized method.