JR East has set down strict rules for checking the worksite after work in light of the collision between a train and the bucket of a backhoe that occurred on the Keihin Tohoku line. However, the checking method is just visual checking by personnel such as work managers, and it still relies solely on human attention. And even after setting down rules, operation disruptions due to tools left at the work site reoccurred. So we decided to develop a backup system for physical aspects limited to larger tools that can greatly affect train operation if left.

We developed a system using multipurpose technology for frontline work sites to prevent leaving larger tools on the track. Development was conducted based on the current working situation and checking after work. The prototype system was then examined in actual work. This article will report on field tests conducted with an aim of developing a mass-production model for future introduction.

**Keywords:** Post-work checking, Leaving tools behind, Human error, RFID, Sheet antenna

### 1 Introduction

In light of the collision between a train and the bucket of a backhoe that occurred in the section between Oimachi and Omori on the Keihin Tohoku line on October 6, 2003, we put together rules for checking after maintenance work including a post-work checking manual to prevent reoccurrence of such an accident. Still, some incidents related to post-work checking occurred such as the collision between a train and a trolley on the Ofunato line in June 2008. In light of those circumstances, we decided in October of 2008 to develop a support system for post-work checking of larger tools left on the track that would hinder safe train operation if a train collided with them.

In order to minimize the burden of new work in post-work checking using the system, we studied a method of checking that would not interfere with the usual workflow. As a result, we decided to check the number of tools loaded on the carrier vehicle. Workers load necessary tools on that vehicle at the office before leaving for the worksite and also load used tools on the carrier vehicle before returning to the office. In this basic workflow, we put together a system to systemize checking of tools by detecting and managing the loaded tools through simple operations (Fig. 1).

### 2 Configuration of Post-work Checking Support System

We decided to adopt RFID technology as the method of detecting tools. We chose a 300 MHz band active tag method of RFID detection, and we developed a sheet type antenna that would have trigger coils of flexible shape and a receiving antenna built in to a truck sheet. To detect tools that are temporarily placed out of the clearance gauge in actual work, we also developed a method of reading passive tags attached to tools with a handy terminal.

#### 2.1 Sheet Antenna

1) System automatically detects tools when they are loaded on the carrier vehicle
2) System checks the number of the tools and manages data within the system
3) Whether or not any tools are left behind is determined by crosschecking tool data before and after work
4) Work manager etc. determines presence of clearance gauge interference based on determination results by the system and post-work check results according to the current manual checking post-work

Fig. 1  Image of Automatic Detection of Loaded Tools

Fig. 2 shows the configuration of the post-work checking support system. The system consists of the following components.
- Sheet antenna that checks loading of tools
- Onboard data transfer device that emits signals the sheet antenna
- Handy terminals that read temporarily placed tools and operate various devices
- IC tags attached to the tools (active/passive)
- Control terminal in which items such as tools and track work managers are registered
As the first phase of the development, we carried out basic tests. The objectives of those tests were to find the best placement pattern of the trigger coils and the receiving antenna built in the truck sheet and to check detection performance.

Since the prototype sheet antenna produced for the basic tests had some areas of weak trigger magnetic field, we were concerned that active tags shielded by tools might not respond. Thus, we placed trigger coils so that they would construct four loops on a sheet as shown in Fig. 3. Each loop independently generates a trigger magnetic field so the areas with weak trigger magnetic field can be covered.

In order to prevent interference of reading active tags due to reflection or shielding by metal parts of tools and other items, we used eight receiving antennas placed on the sheet antenna. Doing so improved receiving sensitivity (Fig. 3).

2.5 Selection of Handy Terminal and Passive Tag

The handy terminal is used for more than just checking of temporarily placed tools. It is also used for input and control of the number of such tools before and after the work by being connected to the onboard data transfer device.

Taking into account IC tag reading ability, the interface for connecting to devices such as the onboard data transfer device and portability required for this system, we selected the BHT-604QUWB by Denso Wave Incorporated as the handy terminal.

A passive tag responds with its tag ID to the handy terminal upon receiving signals from that terminal. Taking into consideration reading range, performance, environmental resistance and impact resistance, we selected Omni (MAX) for the passive tag (Table 1).

### 3. Study of System Operation

#### 3.1 Registration of Tool Name (Identifying Tools with Tags)

Tools are detected by reading IC tags on the tools. In order to identify the tool by reading, we made so tag IDs are related to tool names. That enables tool names to be displayed by reading the IC tags.
3.2 Study of System Installation
In operating the system, we examined how to install the onboard data transfer device and the sheet antenna to the carrier vehicle. Based on the results of that examination, we decided to put an onboard data transfer device, charger/communication unit, handy terminal and mobile printer in a special carrying case as a mobile unit to meet the following requirements.

i) Make connection between the onboard data transfer device and the sheet antenna uniform regardless of the carrier vehicle type

ii) Enable easy installation and removal of the onboard data transfer device for the following cases
   - Reading tools on multiple carrier vehicles with one onboard data transfer device
   - Returning the data transfer device to the manufacturer due to failure, etc.

iii) Have sufficient durability against adhesion of water, oil, metal powder and chemicals and against external influences such as vibration, high/low temperature

3.3 Production of Prototype Carrying Case
Fig. 4 shows the prototype special carrying case and the equipment in it. The cable from the waterproof box of the sheet antenna is connected to the cable from the side of the case.

The carrier vehicle supplies power for the equipment in the carrying case and the sheet antenna by connecting the power cable of the onboard data transfer device to the in-vehicle power port socket.

3.4 Workflow
Fig. 5 shows the workflow when using the post-work checking support system.

This system is used at the office, on the carrier vehicle that carries tools and materials to the worksite and at the worksite. Its main function is data transmission to system components using the handy terminal.

The control terminal at the office has the following functions.

i) Functions for jobs done at every addition/change of tools
   - Registration of the tool (identification of the tool with the IC tag)
   - Data input of line names and track work managers

ii) Functions for jobs done at every work instance
   - Registration of work history (tool use history)
   - Display and print out of record forms

3.5 Performance Evaluation
We conducted performance evaluation tests using the prototype system (Fig. 6). Loading larger tools to be handled by this system on the carrier vehicle at random, we checked whether the sheet antenna correctly detected active tags. As shown in Table 2, the tests delivered good results.
4 Improvement and Testing of the Post-work Checking Support System

4.1 Issues with the Prototype System

The post-work checking support system showed good performance; however, it still had the following issues in terms of practical use.

(1) Downsizing of special carrying case

The prototype carrying case occupies the passenger’s seat or the space for one person on the rear seat in the small cabin of the carrier vehicle.

(2) Reducing time for connecting onboard data transfer device and sheet antenna

Connecting the onboard data transfer device to the sheet antenna with nine cables results in poor workability because connection work is troublesome and takes time.

(3) Environmental resistance of onboard data transfer device

The onboard data transfer device of the prototype system showed no problems with operation in temperature tests between -20 degrees and +60 degrees using one sample data transfer device. However, further verification tests are needed for use in actual work.

4.2 Improvement and Tests of the Prototype System

To improve the aforementioned problems, we produced an improved prototype system. The existing prototype has been undergoing tests by the frontline track maintenance company since the summer of 2010 to evaluate environmental resistance and operability.

(1) Testing of Existing Prototype

The existing prototype system has been undergoing tests by the track maintenance company in the greater Tokyo area since July 2010 and in the Tohoku area since February 2011 (Fig. 7). As of February 2011, we have seen no functional problems with that prototype. In interviews regarding its use, we received comments mainly on operability as shown in Table 3.

Table 3 Comments Received During Test

<table>
<thead>
<tr>
<th>Device</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onboard data transfer device</td>
<td>- There were many connectors.</td>
</tr>
<tr>
<td>Sheet antenna</td>
<td>- Special carrying case occupied the space</td>
</tr>
<tr>
<td></td>
<td>for one person on the rear seat.</td>
</tr>
<tr>
<td></td>
<td>- All active tags were read with the sheet</td>
</tr>
<tr>
<td></td>
<td>antenna.</td>
</tr>
<tr>
<td>Handy terminal</td>
<td>- It would be more usable if a function to</td>
</tr>
<tr>
<td></td>
<td>indicate the current processing step was</td>
</tr>
<tr>
<td></td>
<td>added.</td>
</tr>
<tr>
<td></td>
<td>- The handy terminal had to be held very</td>
</tr>
<tr>
<td></td>
<td>close to passive tags to read.</td>
</tr>
<tr>
<td>Other devices</td>
<td>- Printing of results is usually done at the</td>
</tr>
<tr>
<td></td>
<td>office.</td>
</tr>
</tbody>
</table>

(2) Production of Improved Prototype

Based on the issues covered in 4.1 and the comments received in testing, we produced an improved prototype system. The improved points are as follows.

i) Unifying cables between onboard data transfer device and sheet antenna into one connector

The previous prototype has to connect the onboard data transfer device to the sheet antenna with nine cables including a power cable, causing poor workability. As shown in Fig. 8, we could unify eight antenna cables and a power cable into one connector with the improved prototype system, achieving better workability.

ii) Downsizing special carrying case

By downsizing the onboard data transfer device, we could make the special carrying case smaller.

Fig. 8 Improvement of Connector
(left: improved prototype, right: previous prototype)

5 Conclusion

In this research, we proposed systemizing checking of the number of tools, limited to larger tools as a method to support checks after maintenance work that rely only on human attention, and we produced a prototype of that system. Then, we produced an improved prototype system. We are now verifying operability and environmental resistance of both prototype systems. Based on the verification results, we will propose specifications for a mass-production system.

Reference: