Abstract

The employment of a third rail type current collecting shoe gear is prescribed in Korean standard specifications for the rubber tired AGT system. Based on the Korean rubber tired AGT specifications, a third type shoe gear was developed. It has a simple link mechanism and spring action so that interruption with conductor rails is minimized and the life cycle of shoe is lengthened. As the rolling stock gauge and the requirements for the rubber-tired AGT R&D project, the prototype is designed and manufactured. With a rotary disk type equivalent testing equipment, the wearing of shoes and interruption with conductor rails are evaluated.

Keywords: Rubber-tired AGT(automated guideway transit), Korean standard specification, Third rail, Current collecting shoe gear, Interruption, Shoe wearing, Contact force.

1. Introduction

There are two electrification systems in the urban railway, one is third rail type and another is overhead catenary type. In general a third rail type current collecting shoe gear is the most common type of practical use in the rubber-tired AGT system, since it is more efficient and economical than an overhead catenary/pantograph in conventional electric railways and subway systems[1-4]. The third rail type does not require catenary facilities and may reduce a cross section area of tunnel. As considering construction and maintenance cost, environment, scenery in the urban, Korean standard specifications for the rubber tired AGT system proscribes the employment of third rail[5].

Since the rubber-tired AGT system has been being considered more efficient and economic than the conventional urban railway transportation(subway), and a medium transport system for urban and suburban services in Korea, government had established the standard specification for light rail transit in 1998. Based on the standard specifications, research and development project for the rubber-tired AGT system has been performing from 1999 to 2003. In the rubber-tired AGT system, the vehicles run on concrete track with rubber-tired wheels and are driven by an induction motor. Therefore two rigid conductor rails, one is positive and another is negative, must be installed at one side or both side of running track. A current collecting shoe gear must be installed at both sides of vehicle because one is used for forward and the other is used for backward.

In this paper, the third rail type current collecting shoe gear composed of a simple link and spring mechanism is proposed, so that interruption with conductor rails is minimized and the life cycle of shoe(slider) is lengthened. Based on Korean standard specifications and the requirements in the R&D project, the prototype is manufactured. With a rotary disk type equivalent testing equipment, the wearing of shoe and interruption with conductor rail are evaluated.

2. Design and manufacturing

2.1 Design requirements for shoe gear

For the satisfactory feeding electricity to vehicle, the shoe gear used on the rubber tired AGT system should provide minimum weight, low dynamic mass, low interruption and minimized wearing of collecting shoe. Size of it, furthermore, should be contented with rolling stock gauge. In Korean standard specifications and requirements for the rubber tired AGT system, third rail type shoe gear is regulated to be satisfied with followings[1,2,5].

1) low wearing of collecting shoe

The wearing of collecting shoe is a key determinant of the performance of a shoe gear because it is related with maintenance cost. Wearing is generally defined as the loss of shoe as a result of sliding action between shoe and conductor rail. There are two sources in the shoe wearing, one is mechanical wearing by sliding contact and the other is electrical wearing by arc discharge.

2) shock and vibration absorbing as vehicle running

The contact force is composed of a static force component given by the application force and a dynamic force component...
dependent on the shock and vibration of a shoe gear given by vehicle running. Therefore a shoe gear must be designed to absorb shock and vibration.

3) minimized variation of contact force between collecting shoe and conductor rail
It is the function of the current collecting shoe gear to provide continuous and reliable transmission of the electric energy supplied via the conductor rail to the vehicle. The decisive criterion for assessing the contact quality and therefore the quality of the energy transmission is the minimized variation of contact force between shoe and conductor rail[6].

4) A shoe gear may supply the electric energy to the electrical driving units of vehicle, and protect those from the surge.

5) A shoe and shoe arm may be retracted by a removable insulating lever or pneumatic mechanism for emergency or maintenance work.

6) A shoe gear may be replaced easily, and its size and weight must be minimized.

2.2 Structure and functions

1) collecting shoe
The size of collecting shoe had been determined as considering the collector current rating(250A) and vertical deviation in case of tire puncture. As shown in Fig.1, the shoe shape is flat so that contact area is increased. On account of relatively high mass, steel, cast-iron, copper or bronze shoes inflict mechanical damage to the conductor rail. Their high friction has a tendency to create excessive wearing both to the collecting shoe and to the conductor rail. It may result in interruption between collecting shoe and conductor rail, the problems of interference to telecommunications and signaling system. In this paper metalized carbon sintered copper is used to eliminate these problems[7-9]. Fig.1 shows contact condition between collecting shoe and conductor rail.

![Fig. 1 Contact between shoe and conductor rail](image)

Fig. 1 Contact between shoe and conductor rail

2) Mechanism description
As shown in Fig.2 and 3, current is collected by the collecting shoe which is allowed to contact and slide along a conductor rail installed beside the track. The shoe gear developed here are composed of main frame, fuse box, two tensile
springs, articulated shoe bracket, four links, arm and pin joints. Main frame is made of reinforced plastic resin that offers good mechanical properties. In the upper part of the shoe gear watertight fuse box is located and fuse is installed within fuse box. A shoe is fixed to the shoe bracket by bolt joint. A shoe bracket is linked to the arm by pin joints, where a shoe bracket may be articulated to the arm. The allowable articulated angle is about 10[deg]. The contact force between shoe and conductor rail is provided by two tensile coil springs. There is shoe arm made of aluminum alloy, which has a role to connect shoe and main frame. There is a hook to maintain shoe retraction action. Fig.4 shows a photograph for the prototype manufactured.

![Fig. 4 Photograph for shoe gear prototype](image)

2.3 Motion constraints
Since the developed shoe gear will be installed on bogie in urban areas with heavy traffic, size of it must be in the maximum rolling stock gauge of the rubber tired AGT vehicle. As shown in Fig.2 and 3, the shoe gear is designed to satisfy with Korean standard specifications related to the rubber tired AGT vehicle. Furthermore, the envelope curve of shoe and arm is also considered.

3. Test and evaluation

3.1 Test equipment
As shown in Fig.5 a rotary disk type equivalent testing equipment consists of a rotary disk of 1.2[m] diameter on which a circular conductor rail equivalent to one used in the actual rubber tired AGT system is mounted. As the disk is rotated by a driving motor, the circular conductor rail on test equipment comes in to sliding contact with the collecting shoe. The equipment can be operate at a maximum speed of 100[km/h] at which the disk rotates at 530[rpm], and may be capable of speed control. For shoe gear feed, the current is conducted to a circular conductor rail and shoe gear via a slip ring provided on the same shaft as the rotary disk. The capacity of shoe gear may be up to 250[A], which conforms to Korean standard specification and requirement for the rubber tired AGT system.

![Fig. 5 Rotary disk type equivalent testing equipment](image)
A circular conductor rail on the test equipment consists of a stainless steel sheet fixed to an aluminum supporter. This circular conductor rail is similar to the ones employed on DC power electric system. Table 1 shows general specifications of the rotary disk type equivalent testing equipment.

Table 1 General specification of the test equipment

<table>
<thead>
<tr>
<th>Collector capacity</th>
<th>DC 750V, 250A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum speed of disk</td>
<td>100km/h (530 rpm)</td>
</tr>
<tr>
<td>Adjustable range of contact force</td>
<td>80 ~ 150N</td>
</tr>
<tr>
<td>Maximum diameter of disk</td>
<td>1.2m</td>
</tr>
<tr>
<td>Effective diameter contacted with collecting shoe</td>
<td>1.0m</td>
</tr>
<tr>
<td>Collecting shoe</td>
<td>Metalized carbon Sintered copper</td>
</tr>
<tr>
<td>Circular conductor rail</td>
<td>- Stainless steel</td>
</tr>
<tr>
<td></td>
<td>- aluminum</td>
</tr>
</tbody>
</table>

3.2 Measuring of interruption and shoe wearing

1) Interruption between shoe and conductor rail

Interruption between collecting shoe and conductor rail was measured by means of an oscilloscope. Circuit current for measuring the interruption was DC 3[A]. The interruption ratio is indicated as following[3,4,9],

\[ \alpha = \frac{I_i}{I_m} \times 100[\%] \]

where

- \( \alpha \) : interruption ratio[\%]
- \( I_i \) : total time of interruption[sec]
- \( I_m \) : total measuring time[sec]

For the measuring of interruption ratio, the range of contact force was 80~150[N], and the range of speed was 20~70[km/h] because the maximum running speed of the rubber tired AGT vehicle is regulated to 70[km] in Korea standard specification and requirement.

2) Wearing of collecting shoe

After initial weight of collecting shoe was measured (1.0[mg] accuracy), the wear weight loss at the specified speed was measured. For the measuring of shoe wearing, measuring condition is illustrated in Table 2. The sliding surface between the collecting shoe and the conductor rail was maintained in the dry condition.

Table 2 Measuring condition of the shoe wearing

<table>
<thead>
<tr>
<th>electricity</th>
<th>contact force[N]</th>
<th>running speed[km/h]</th>
<th>running distance[km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC 750V (250A)</td>
<td>90, 120, 150</td>
<td>60</td>
<td>300</td>
</tr>
<tr>
<td>no current</td>
<td>90, 120, 150</td>
<td>60</td>
<td>300</td>
</tr>
</tbody>
</table>

4. Results and discussions

4.1 Interruption ratio

Interruption ratio was measured as shown in Figs.6 and 7, which are similar to the steel wheeled AGT shoe gear[9]. With the developed shoe gear used in the rubber tired AGT system, the interruption ratio increased as the increment of running speed, however, decreased as the increment of contact force. Interruption increases the wearing of shoe, therefore reduces the life cycle of the shoe. If the contact force is too high, the wearing of shoe increases because of mechanical wearing. If the contact force is too low on the contrary, the electrical wearing of shoe increases because interruption increases.
As shown in Fig.7, the interruption ratio has a trend to fall with an increase of contact force, however, excessive contact force will result in the reduction of shoe life. There is no interruption below 20[km/h] running speed, which has nothing to do with contact force. The more contact force is increase, the more the running speed without interruption is increase. Therefore, high contact force should be set up in the route with sharp radius.

4.2 wearing of shoe
The running distance in the experiment was equivalent to 300[km] approximately for the actual situation. The wearing of shoe with current conduction was larger than without current conduction as shown in Fig.8, which is similar to the case of steel wheeled AGT system[9]. It was found that electrical waste including arc discharge due to interruption also contributed to the wearing of collecting shoe. The interruption ratio rises as the decrease of the contact force. The wearing of collecting shoe has a trend similar to the interruption ratio. However, mechanical wearing of collecting shoe rises as the increase of contact force in the no current conduction. In order to lengthen the collecting shoe life, contact force should be set up in the optimal range where mechanical wearing and interruption ratio may be minimized. Based on the developed shoe gear, the expected shoe life is more than 25,000km in case that two shoe gear collect current(250A) at one vehicle.

5. Conclusions
Based on the Korean standard specification for the rubber tired AGT system, a third rail type current collecting shoe gear is developed, which is composed of a simple link and spring mechanism so that interruption with conductor rails is minimized and the life cycle of collecting shoe is lengthened. Based on the Korean standard specifications and the requirement, the prototype is designed and manufactured. With a rotary disk type equivalent testing equipment, the wearing of shoe and interruption ratio are measured. It is shown that the developed shoe gear is effective sufficiently to the rubber tired AGT system. The expected shoe life is more than 25,000[km] in case that two current collectors collect current(250A) at one vehicle, the optimal range of contact force is 120[N]. The maximum interruption ratio is less than 4[%] in the maximum vehicle speed 70[km/h] and 130[N] contact force.
[Reference]