Summary

The total weight of the vehicle is one of the important basic parameters necessary in the understanding of vehicle dynamics on the Yamanashi Maglev Test Line. A measurement system was developed to measure the vehicle weight in a short period of time with a minimal number of people, and with high accuracy. In order to minimize the time required for measurement, the weight is measured when the vehicle begins to move out of the train depot at the beginning of the day of vehicle running tests. The effect of the overshoot in the wave shape of the measurement caused by monitoring while in motion is compensated for by specially developed software.

1. Introduction

On the Yamanashi Maglev Test Line, the weight of the vehicle is a basic parameter necessary in the understanding of the vehicle dynamics and other characteristics of Maglev. A system was developed to measure the vehicle weight quickly with high accuracy, requiring minimal manpower. In order to minimize the time required for measurement, the weight is measured when the vehicle begins to move out of the train depot at the beginning of the day of vehicle running tests. No personnel are required to manually take measurements, and the total required measuring time is reduced from about 15 minutes to about just 5 minutes.
2. System overview

When the weight is measured while the vehicle is in motion, a large load difference in the form of an overshoot is observed momentarily at the beginning of the measurement. As a result, if the maximum value is taken to be the weight of the vehicle, there is a possibility of over-estimating the real weight. Because this overshoot is proportional to the speed of the vehicle when the wheels move on to the scales, the measurement system requires that the vehicle move at a low constant speed. Software was developed to resolve this overshoot problem. The wave shape was examined in detail and a very simple algorithm was devised that can isolate and remove the components of the overshoot in the wave shape. The entire system is connected to a LAN (Local Area Network) by radio frequency signals, and also functions as a computer network server. This system can therefore be fully controlled and monitored from every personal computer connected to the LAN, at any designated location. The overall system is shown in Figure 1.

The signals from two load cells (one each for the left and right wheels) are input to strain amplifiers. Two channels are sampled simultaneously, and the signals are converted to digital values by 16-bit A/D converters. The signals converted into digital values are input to a personal computer using a GP-IB interface. When the values exceed a threshold value, a signal is emitted that triggers the start of data recording. The measurement system distinguishes each bogie by an assigned unique ID number. The system automatically begins measuring the weight as a remote device detects the approach of each pair of wheels without physical contact. In addition, it is possible for this system to store the results in the bogie itself. A wireless tag which contains a re-writable ID card with memory for recording weight data and an ID number stored in advance are attached to the bottom surface of each bogie. A transceiver is used to read and write data on the wireless tag. The transceiver for the wireless tag is connected to a personal computer using an RS-232C interface. Visual BASIC computer language was
used to develop software for GP-IB control, RS-232C control, and the overall program. C language was used in the measurement data analysis program.

There are four load cells, organized in two pairs, that are laid on the path of the vehicle in the train depot. Each pair has one load cell on each side to measure the left and right wheels. There are two pairs, one for the north guideway and another for the south guideway. The vehicle weight is measured when the wheels pass over the load cells. The sampling is at 10-millisecond intervals, and the sampling output of the two load cells of a pair are simultaneously processed. When the wheels pass over each pair of load cells, perturbations in the vehicle movements such as those arising from rolling motion are often present. However, these perturbations have no effect on the measurements, because the system performs simultaneous sampling and constantly processes the weight as the sum value of the weights of the left and right wheels.

The overshoot was accounted for in the measurement process as follows. The measured wave form data are stored into cumulative data and categorized into one of several types of characteristic shapes. The measurements are then analyzed and processed using the following algorithm. When the slope of the measured wave form changes only once from positive to negative, the maximum/peak value of all measured data is considered to be the vehicle weight. When the sign (positive/negative) of the slope of the measured wave form changes twice or more, the maximum/peak value of data measured from the second change in the sign of the slope and afterwards is considered to be the vehicle weight. The results of the test data processed by this algorithm is shown in Figure 2.

![Figure 2 Processing and confirmation of the test data](image)

3. Results of the processing performed by the vehicle weight measurement system

The case where the maximum/peak value is selected as the vehicle weight is compared with the case where the measurements were processed by the aforementioned algorithm. This comparison was an assessment not of absolute values, but of the reproducibility of the measurement values. From the measured weight of each bogie and
the load supported by the bogie, the total weight of the passengers on board the vehicle was subtracted. These calculations were performed for two days, and the percent difference between the two days was computed, with a zero percent difference being the ideal case. The results of the comparison are as follows:

When calculated using the maximum/peak values (unit: kgf), the results are as follows:

<table>
<thead>
<tr>
<th>Bogie number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>_</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>15956</td>
<td>19236</td>
<td>20510</td>
<td>20326</td>
<td>76028</td>
</tr>
<tr>
<td>Second</td>
<td>15817</td>
<td>19300</td>
<td>20500</td>
<td>20302</td>
<td>75919</td>
</tr>
<tr>
<td>Difference (%)</td>
<td>-0.871</td>
<td>0.333</td>
<td>-0.049</td>
<td>-0.118</td>
<td>-0.143</td>
</tr>
</tbody>
</table>

When calculated using the overshoot-processing software, the results are as follows:

<table>
<thead>
<tr>
<th>Bogie number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>_</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>15946</td>
<td>19236</td>
<td>20469</td>
<td>20326</td>
<td>75977</td>
</tr>
<tr>
<td>Second</td>
<td>15817</td>
<td>19300</td>
<td>20473</td>
<td>20302</td>
<td>75892</td>
</tr>
<tr>
<td>Difference (%)</td>
<td>-0.809</td>
<td>0.333</td>
<td>0.020</td>
<td>-0.118</td>
<td>-0.112</td>
</tr>
</tbody>
</table>

As shown above, further improvement in the reproduction of the results is demonstrated. By applying this method, the margin of error for an accurate measurement of a vehicle with a weight of 76,000 kgf (76 tonf) is approximately 0.1% maximum when the vehicle is in motion, approximately equivalent to the weight of one passenger. The data from the first measurement and its magnified wave form are shown in Figures 3 and 4.
4. Conclusion

The automatic remote-controlled weight-measurement system for the vehicles on the Yamanashi Maglev Test Line has the following characteristics:

- The weight can be measured with high accuracy while the vehicle is moving, with the previous total required measuring time of about 15 minutes being reduced to the current time of about just 5 minutes, while also reducing the required manpower.
- The measurement system can be activated and monitored from any remote location. Because this measurement system is connected to a computer network, this system can be controlled and monitored remotely from other personal computers.
- Measurement begins automatically when each bogie approaches the measuring device, with each bogie being distinguished by a unique ID number that is automatically detected by the measuring device.
- The results of measurements are also stored on board the vehicle in data storage devices attached to each bogie.
- This system can be used to monitor the weight daily, and maintain a cumulative record of the weight of each bogie.

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