A Fuzzy based Treatment to reduce Air-gap Disturbance at the Rail Joints with Step-wise Rail joint

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ABSTRACT: Maglev using EMS becomes unstable by unexpected big air-gap disturbance. The main causes of the unexpected air-gap disturbance are step-wise rail joint and large distance between rail splices. For the stable operation of the maglev, the conventional system uses the threshold method, which selects one gap sensor among two gap sensors installed on the magnet to read the gap between magnet and guide rail. But the threshold method with a wide bandwidth makes the discontinuous air-gap signal at the rail joints because of the offset in air gap sensors and/or the step-wise rail joins. Further more, in the case of the one with a narrow bend-width, it makes maglev system unstable because of frequent alternation. In this paper, a new method using fuzzy rule to reduce air-gap disturbance is proposed to improve the stability of maglev system. It treats the air-gap signal from dual gap sensors effectively to make continuous signal without air gap disturbance. Simulation and experiment results proved that the proposed scheme was effective to reduce air-gap disturbance from dual gap sensors in rail joints.

1 INTRODUCTION

The development of Maglev System as an urban transportation system has been achieved actively to solve the traffic jam in the inner city. Compared to the vehicle suspended by steel wheels, Maglev systems take a lot of advantages, which are less noise, less operating cost and the outstanding transit ability. Maglev is roughly divided to EMS and EDS by the levitation method and the Maglev system using the permanent magnets has been studied recently. [1][2]

The high-temperature superconducting magnetic levitation train is not only a stable system but also doesn't need the levitation control because it can be levitated above 100mm by the repulsive force from induced current in levitation coils when the superconducting magnets are passing it. But the disadvantages of this type vehicle are that it needs cooling system and incidental facilities in vehicle and its ride quality is bad because this type vehicle makes the perturbation toward vertical direction when it is running.

EMS system is suspended by the attraction force to rail generated from the electric magnets of vehicle and keeps the levitation level which is about 8~11mm to consider energy efficiency. This type vehicle needs less expense than EDS system and is good in ride quality. But it needs active control to keep fluctuation within 2~3mm between electric magnetic and rail when it is running. UTM (Urban Transmit maglev) was developed and has been studied in KIMM (Korea institute of Machinery and Materials) as an EMS system and it uses Linear Synchronous Motor to propel. To achieve the reliable control about levitation is important for commercial applications. There is no perturbation without running but running on the rail makes perturbation in levitation control by varying plant structure or unknown dynamics and by guide-way irregularities and rail joint.

In this paper we studied the air-gap treatment to minimize the effect from guide-way irregularities and rail joint.

2 THE OUTPUT SIGNAL TREATMENT OF DUAL AIR-GAP SENSORS

2.1 *A conventional method using dual air-gap sensors [3]*

When Maglev vehicle passes the rail-joint, the research for improving the ride quality of Maglev system with an air-gap sensor in each corner of a bogie has been studied before. But it is not acceptable to Maglev system for practical use. So the threshold method which selects one of gap sensor between gap sensors installed on the levitation magnet in order to measure the distance between magnet and guide rail is proposed.

The air-gap disturbance occurred from passing on the rail-joint without step-wise is shown in Figure 1 and the air-gap disturbance occurred from passing on the rail-joint with step-wise is shown in Figure 2 The conception block diagram for threshold method with two gap sensors in each corner of a bogie is shown in Figure 3. In figure 1, the relationship for the measured signal voltage between two gap sensors when maglev system is passing the A point is $V_{gap1} > V_{gap2}$ and $V_{diff} > +V_{th}$. In that case, the second gap sensor will be chosen. If the vehicle is passing the B point, the first gap sensor will be chosen.

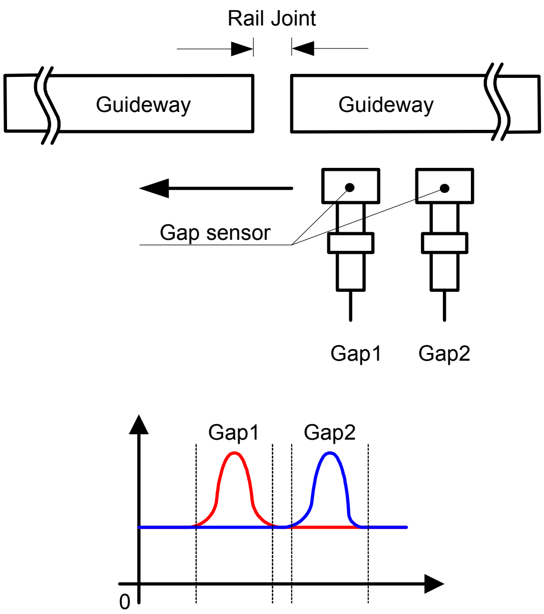

Figure 1: air-gap signal during vehicle running (guide-way without step wise)

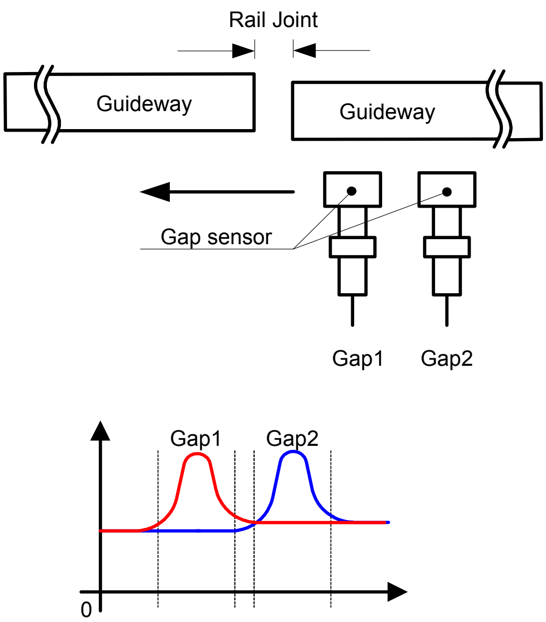

Figure 2: air-gap signals during vehicle running (guide-way with step wise)

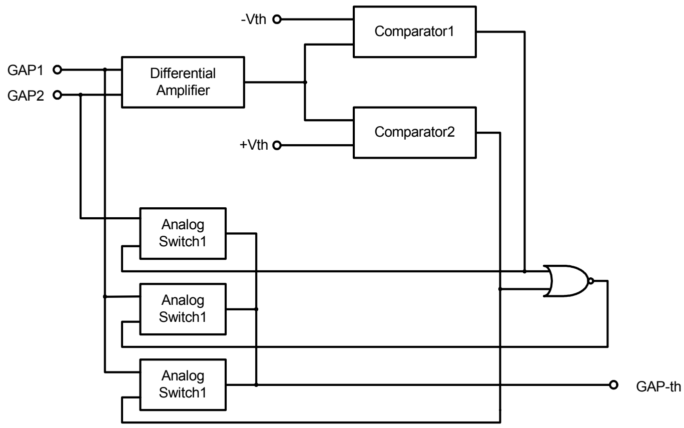

Figure 3: the block diagram for the gap signal treatment of the dual gap sensors

2.2 *The signal treatment of dual air-gap sensors based on Fuzzy rule*

A conventional method using dual air-gap sensors is that one value of two air-gap sensors is selected and then is held before it overflows the threshold value that already defined the range for air-gap output. If it is overflowed, the other value of two air-gap sensors is selected. Therefore air-gap disturbance from threshold between two air-gap sensors cause often instability of the EMS system and those increases the air-gap error at the levitated state.

In this paper the signal treatment of dual air-gap sensors based on the Fuzzy rule is easier to manage the wide range air-gap signal. If the values of two air-gap sensors are different, Fuzzy based air-gap treatment method makes an average for out-values of two sensors. And if there is a wide difference between output values of two air-gap sensors, it makes reasonable value for the output value of two air-gap signals.

Fuzzy membership function for the output value of dual air-gap sensors is shown in figure 4 and Fuzzy rule is shown in figure 5. Fuzzy inference engine uses Min-Max method to meet the designed object and the gravity method is selected for Defuzzifier. The final results are made by adding the DC value from the average of two air-gap output signals to the defuzzified value.

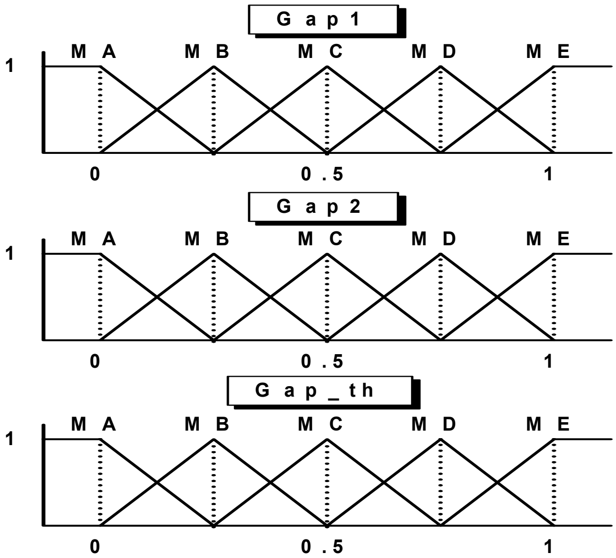

Figure 4: Fuzzy Membership Function

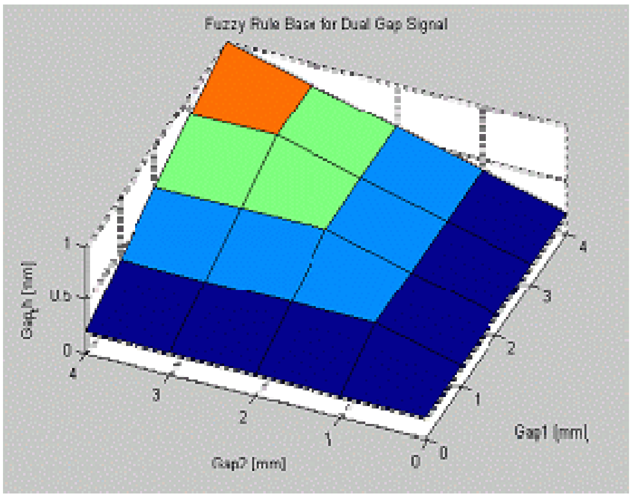

Figure 5: Fuzzy rule base

2.3 Simulation

In this paper, Matlab/Simulink is used in order to prove the control performance using Fuzzy rule for air-gap signal selection and the database acquired from dual air-gap sensors is used for air-gap signal in simulation to confirm that the proposed signal treatment using Fuzzy rule is applicable to the air-gap signal treatment of Maglev system. Running on the guide-way without step-wise, the air-gap output signals from dual sensors and the gap signals dealt with Fuzzy rule are shown in figure 6

From the figure 6, running slowly on the guide-way without rail-joint, the Fuzzy rule based method makes the average of dual gap signals and running on the guide-way with rail-joint, it selects the gap signal not to have an effect from rail-joint. So it always makes an attenuated gap signal. Running speedily on the guide-way with stepwise rail joint, the air-gap output signals from dual sensors and the gap signals dealt with Fuzzy rule are shown in figure 7. From the figure 7 the Fuzzy rule based method makes the gap signal not to have an effect from rail-joint.

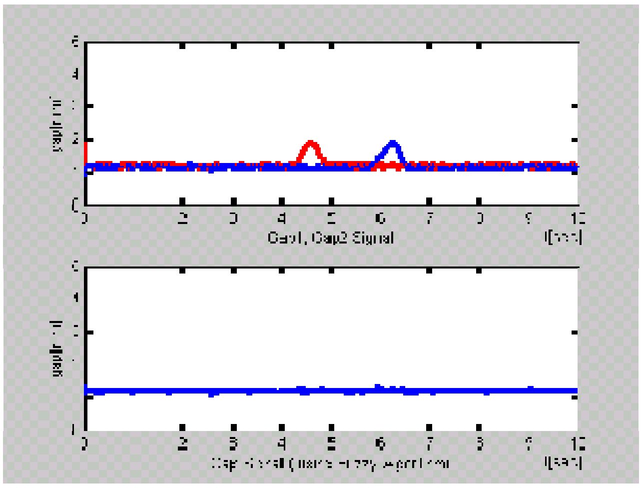

Figure 6: air-gap signals and the managed signal based on Fuzzy rule (guide-way without step-wise rail joint)

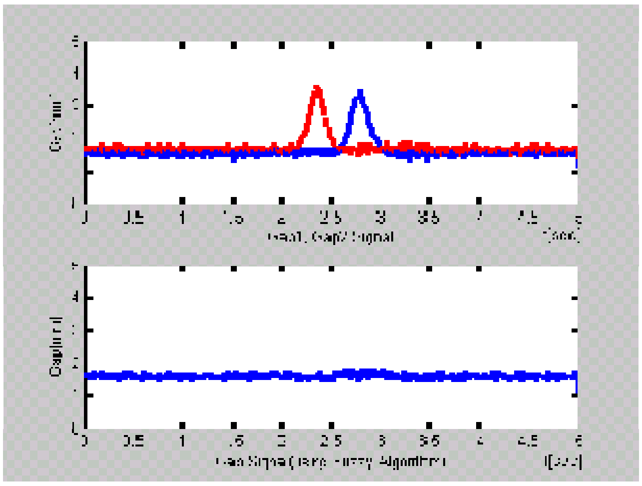

Figure 7: air-gap signals and the managed signal based on Fuzzy rule (guide-way with step-wise rail joint)

2.4 Simulations and Considerations

When the vehicle is running on the guide-way without step wise, the output signals from dual gap sensors and the managed air-gap signal from threshold selection method are shown in figure 8. From the results, we can confirm that the managed air-gap signal from threshold selection method makes the air-gap disturbance as large as threshold value but the Fuzzy rule based method makes the attenuated gap signal.

When the vehicle is running on the test jig, the output signals from dual gap sensors and the managed air-gap signal using Fuzzy rule are shown in figure 9. From figure 9, the Fuzzy rule based method makes the average of dual gap signals and selects the gap signal not to have an air-gap disturbance from rail-joint. From the above results, we confirm that the proposed Fuzzy based method is applicable to commercial applications.

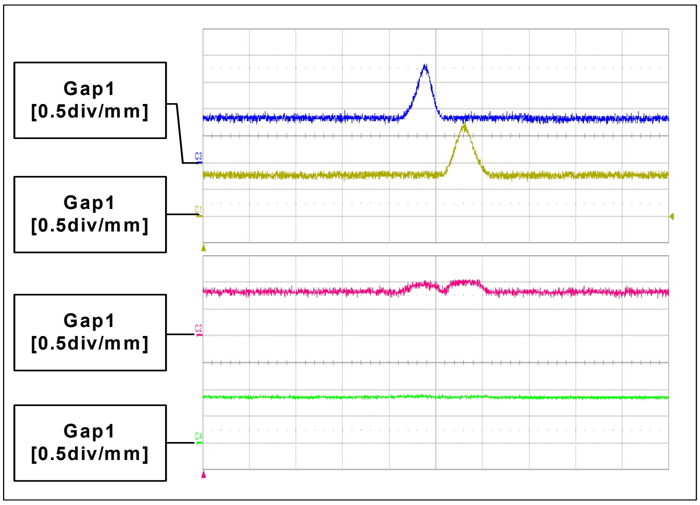

Figure 8: The output signals from dual gap sensors, the managed air-gap signal from threshold selection method and the air-gap signal using Fuzzy rule (guide-way without step-wise rail joint)

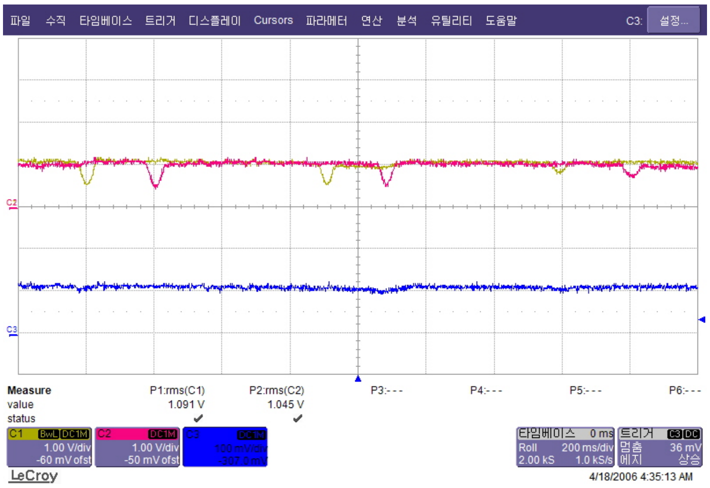

Figure 9: the air-gap signal using Fuzzy rule (running guide-way with rail joint)

3 CONCLUSION

It is important to develop the robust and reliable control system for EMS system. In this paper, we analyzed the conventional method which can makes a problem for levitation system and proposed Fuzzy rule based methods which can attenuate the air gap disturbance. To prove the usefulness of the proposed method, simulation and experiment is performed.

From the above results, whether vehicle is running speedily or not, the proposed method can minimize the air gap disturbance from rail joint and also deal with the air gap disturbance effectively.

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