Magnetic Noise Analysis of Traction Power Converter in Shinkansen Bullet Train

T. Fukuzumi[1], A. Otake[1], S. Wakao[1], T. Okutani[2], M. Saito[3], A. Toyoda[3], M. Morita[4], A. Yajima[4], K. Tashiro[5], N. Kudo[5], Y. Nakahata[6], and T. Shiromizu[6]
[1]Department of Electrical Engineering and Bioscience, Waseda University, Tokyo 169-8555, Japan
[2]Railway Engineering Co., Ltd, [3]The Nippon Signal Co., Ltd, [4]Toshiba Corporation,
[5]National Traffic Safety and Environment Laboratory, [6]Kyushu Railway Company
wakao@waseda.jp

Abstract — Focusing on the EMC problems of railway signaling systems, the magnetic field radiated from PWM traction converter/inverter unit of Shinkansen bullet train was measured precisely. The result matches well to the finite element analysis of the magnetic field surrounding the unit. Furthermore, the effective information for magnetic shield design is also revealed by the computational results.

I. INTRODUCTION

In recent years, electric railcars, such as the Shinkansen bullet trains in Japan, have induction motors with the PWM control system. It is known that PWM converter/inverter (C/I) generate the sideband wave currents of even harmonics of control carrier frequency. The harmonic currents serve as a disturbance for the ATC (Automatic Train Control) system [1]. Furthermore, the stray magnetic fields due to the currents cause the EMC problems [2-5] in the railway signaling systems. When we develop new railway signaling devices, we need to consider the protection against the magnetic noise. The noise reduction is especially indispensable in the case of the wheel detector, which is one of the most important railway signaling devices for accurate and safe train control systems [6]. Therefore, it is very important to precisely comprehend the distribution of magnetic fields generated by the traction power converter of the railcar.

Although there are many reports until now about the survey and the theoretical analysis of disturbance currents which are included in rail current, there are few the measurements and numerical analyses of stray magnetic fields surrounding the traction power converter of the railcar. With this background, this paper carried out the measurement and finite element analysis of magnetic fields generated by the traction power converter in Shinkansen bullet trains.

II. MEASUREMENT OF MAGNETIC FIELD

The survey result of the magnetic noise generated by the traction power converter of the Shinkansen is reported. The gauss meter 9903 and the 3-axis probe ZOA99-3208 produced by F.W.Bell were used for the magnetic field measurement. The measurement data was recorded by the memory high coda (HIOKI 8860). The outline of the measurement is shown in Fig. 1.

As a result of performing prior magnetic field measurement near the storage box of C/I, the magnetic fields of 3-4 mT were measured for all three axes of xyz under the converter box side, and the fields under the inverter box were less than 1 mT. Therefore, the magnetic field was mainly measured in the side of the converter box.

The points of measurement of magnetic fields are shown in Fig. 2. We applied the FFT analysis to magnetic measurement results and extracted their 50Hz frequency component. Fig. 3 shows the measurement results in the shaded area in Fig. 2.

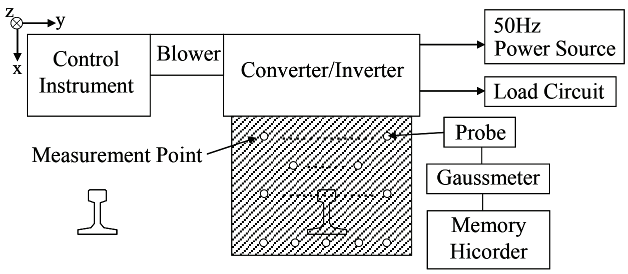


Fig.1. Outline of measurement experiment.

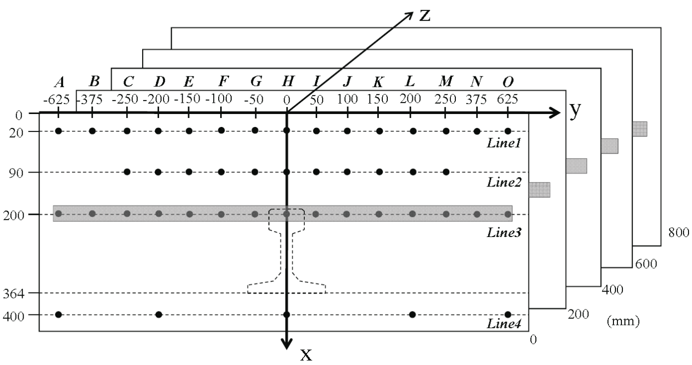


Fig.2. Measurement points of magnetic flux density.

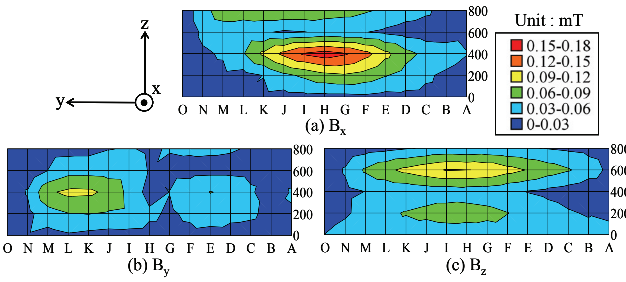


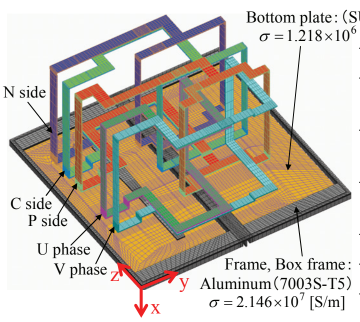
Fig.3. Measurement values of magnetic flux density (50Hz).

III. MAGNETIC FIELD ANALYSIS BY FEM

We performed the finite element analysis of magnetic fields generated by the traction power converter.

The internal electricity wiring of converter and a storage box were modeled as shown in Fig. 4. The side and the upper surfaces of storage box were also included in the analysis model; even they are not shown in Fig.4. The analysis specifications are also shown in Fig.4. Taking account of skin effects, we appropriately provided the fine meshes, i.e., the total number of elements is about 2,200,000.

Fig. 5 shows the numerical results of magnetic fields in the shaded area in Fig. 2 when 50Hz alternating currents flow in U phase and V phase (they are in reversed phase relation). The magnetic flux distributions in the broad plane of x=200mm are also illustrated in Fig 6.



Number of nodes	2,251,710
Number of finite elements	2,213,190
Number of unknowns A	6,716,318
Number of unknowns ϕ	575,095
Memory requirement	7.5 GB
CPU Time	14.5 h

* Computer used : Xeon 3.00GHz

Fig.4. Investigated model and specifications of analysis.

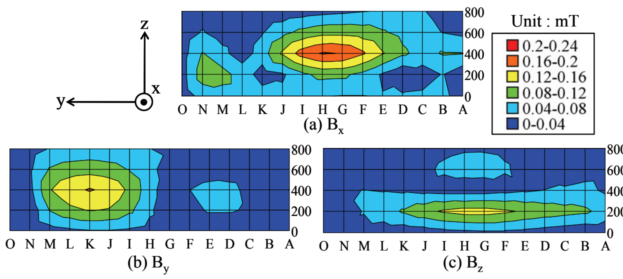


Fig.5. Computational values of magnetic flux density (50Hz).

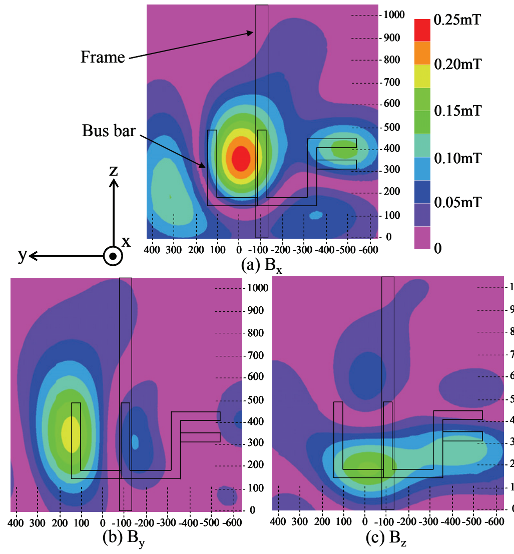


Fig.6. Distributions of magnetic flux density (50Hz).

IV. COMPARISON BETWEEN MEASURED AND NUMERICAL RESULTS

From Figs. 3, 5, and 6, the strong magnetic flux density was confirmed right under the portion where bus bar of each U phase and V phase is separately set.

We compared the actual measurement and calculated values of 50Hz magnetic field in Figs. 3 and 5, and found that both distributions were well in agreement. Therefore we can confirm the validity of the analysis. We can consider the following as countermeasures for the reduction of magnetic noise from the above result. (1) Install shielding plate directly under bus bars. (2) U-V phases should be in one package as much as possible, if bus bars are located in the area which is close to a signal apparatus.

The shield design based on the FE analysis will be discussed in more detail in the full paper.

V. REFERENCES

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