Study on Effective Loading Pattern of Magnetic Sheet Attached on WPT System

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Abstract **- Wireless Power Transmission (WPT) system in accordance with Qi standard is being installed in smart phone in recent years. However, the transmission efficiency is greatly deteriorated due to adjacent metal objects. To solve this problem, magnetic sheet with high permeability is inserted between WPT-coil and metal objects. In order to make thickness of these materials thinner and improve the transmission efficiency, the amorphous magnetic sheet use is proposed in this report.**

Index Terms **— Coupling coefficient, Electromagnetic induction, Qi standard, Quality factor, Transmission efficiency, Wireless Power Transmission (WPT)**

1. Introduction

Wireless Power Transmission (WPT) system in accordance with Qi standards [1], [2] is being installed in smart phone in recent years. The principle of electromagnetic induction is adopted for the WPT system, but its efficiency greatly deteriorated due to adjacent metal objects such as battery cases [3]. In this case, to prevent from the eddy current appearing, the magnetic sheet with high permeability is inserted between the WPT-coil and the metal object. In this report, in order to suppress thickness and improve the transmission efficiency of WPT-coil with adjacent metal objects, verification results of the magnetic loss control with the amorphous magnetic sheet shape transform are shown.

2. Outlines of the wireless power transmission system in accordance with Qi standards

(1) Basic configuration of WPT system for mobile communication gear

In the Qi standards, three kinds of positioning procedures are provided for WPT-coils [1], [2]. Some design admissibility is given for the receiver though the transmitter specification is strictly regulated in this standard. There are three kinds of transmitter regulation, and the receiver design that adapt to them is important task. Particularly, transmitter coil is divided into two types about whether to use magnet or not. In case of the autonomic positioning type which transmitter has a guidance magnet at the center of coil for sucking up the receiver coil, it is thought that the magnetic sheet performances are deteriorated with its guidance magnet. On the other hand, the position tolerance type transmitter has a simple planar transmission coil.

(2) Basic theory for WPT system

Actual shape and the location situation of the transmitter coil (expressed as Tx-coil in Figure 1) and the receiver coil (expressed as Rx-coil in Figure 1) are shown in Figure 1. A metal plate which simulated a metal object in smart phone is located at the neighborhood of Rx-coil.

Two study models for the magnetic sheet insertion to Rx-coil are set depending on the use type of Tx-coil.

Model-1: Study model which uses Tx-coil without guidance magnet type.

Model-2: Study model which uses Tx-coil with guidance magnet type.

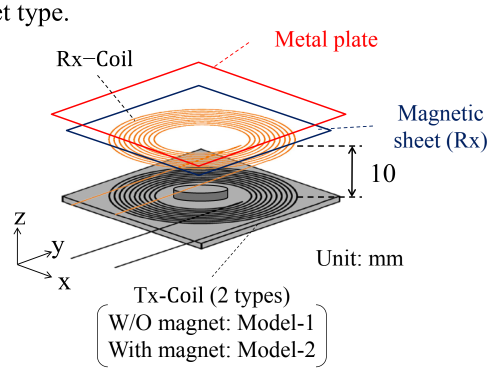

Fig. 1. Transmission coil of Qi standard.

The properties and dimension of magnetic sheet used for study are listed in TABLE I. The sintered ferrite sheet besides the amorphous sheet is prepared for the measurement.To consider the dependence on thickness of magnetic sheets, amorphous sheets are prepared 20 to 80 layers μm. The coil's effective impedance is strongly influenced with the relative permeability of attached magnetic sheet [4]. Additionally, Rx-coil in WPT system is expected to be able to be thinned when high permeability sheet like amorphous sheet is attached in the vicinity of Rx-coil. On the other hand, an increase in the use amount of the high permeability sheet like the amorphous sheet contributes to the increase of the transmission loss because it has a lot of losses.

TABLE 1
The characteristic of magnetic sheet

Magnetic sheet	*Permeability μ'*	*Permeability μ"*	*Thickness* [μm]
Amorphous	8000	5500	20 ～
Sintered ferrite	65	0.5	300

Consequently, to find a moderate use amount of the high permeability sheet, the expression (1) is defined as sheet use amount index ‘Φ’.

$$\Phi \equiv S_{sheet} / S_{coil} \quad (1)$$

where 'S_{sheet}' is the surface area of amorphous sheet and 'S_{coil}' is the surface area of Rx-coil. The outer diameter of amorphous sheet is fixed in 43 mm which equals to Rx-coil’s one. Figure 2 shows the shape example of amorphous sheet. The doughnut-pattern amorphous sheet is used in Fig. 2(c). In case of the doughnut pattern, the inner diameter of amorphous sheet (expressed as 'r_{in}' in Fig. 2(c)) is used as optimization parameter. 'r_{in}' has been changed between from 0 to 30mm in following chapter. Fig. 2(b) is an example from which circular amorphous sheet is used. Also, the square shape amorphous sheet which involves Rx-coil is used in Fig. 2(a).

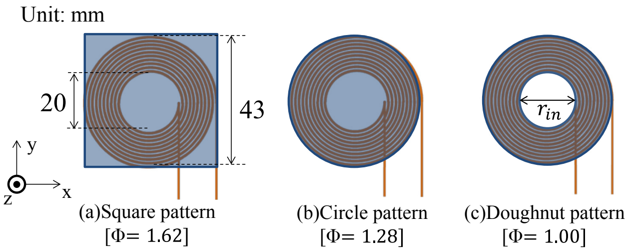

Fig. 2. Loading shape pattern of amorphous magnetic sheet attached with Rx-coil.

3. Evaluation results of the transmission efficiency

In this chapter, results of the transmission efficiency measured with study models shown in the previous chapter are described. The operating frequency set to 150 kHz in each study model and input voltage set to 5.0V. Measurement results of the transmission efficiency with two study models are shown in Figure 3. The dotted line in Fig. 3 is the situation of sintered ferrite attached (thickness of 300 μm) with Rx-coil. In model-1 shown in Fig. 3(a), the proportional relation is found between the efficiency and 'Φ'. The amorphous sheet of square pattern (Φ=1.64) can achieve the transmission efficiency equal with the sintered ferrite in 300μm thickness. On the other hand, in model-2, when the doughnut-pattern amorphous sheet (around Φ=1.00) of 40 μm in thickness is used, the transmission efficiency at the same level as the sintered ferrite of 300 μm in thickness can be achieved. Thickness of 40 μm is more less than 1/7 than thickness of the sintered ferrite.
As results, the doughnut pattern is recognized as the effective loading shape. The reason for this phenomenon is thought as follows. Magnetic flux with the guidance magnet of Tx-coil causes magnetization saturation to the amorphous sheet in vicinity of Rx-coil. As a result, the transmission efficiency turns worse. On the other hand, when the amorphous sheet is shaped as the doughnut pattern, the expansion of the magnetization saturation fringe might be controlled with the inner hole edge of doughnut.

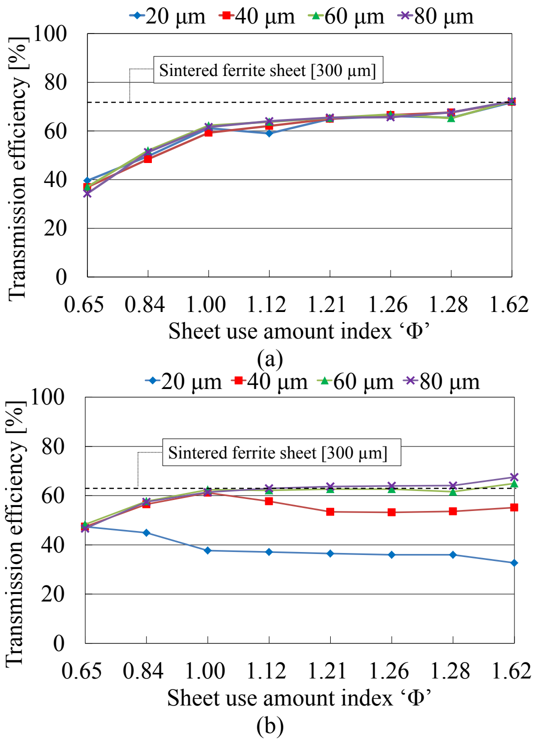

Fig. 3. Measurement result of Transmission efficiency vs Occupancy ratio of amorphous sheet. (a) Case of Model-1, (b) Case of Model-2.

4. Conclusion

In this report, in order to suppress thickness and improve the transmission efficiency of WPT-coil with adjacent metal objects, verification results of the magnetic loss control with the amorphous magnetic sheet shape transform were described. In the study model-1 with Tx-coil without guidance magnet, the proportional relation is found between the transmission efficiency and sheet use amount index 'Φ'. On the other hand, in the model-2, the transmission efficiency depends on not only 'Φ' but also the amorphous sheet thickness. In this model, it is important to prevent the influence of static magnetic flux. Therefore, the doughnut pattern is recognized as the effective loading shape.

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