Induction Heating Technology for System Optimization

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Abstract

Due to global warming, lower the power consumption of electronic device getting more important in recent days. For printing device industry, highly efficient fusing device becomes more important to reduce the power consumption of printer and MFD (Multi Function Device). As the fuser consumes up to 70% of whole energy during the electrophotographic printing process, it is necessary to reduce the power consumption of fuser in printing device. Therefore, induction heating (IH) which could greatly reduce the power consumption of the fusing device and could meet the TEC (Typical Electric Consumption) rate limit is employed. However, the induction heating fusing device's thin heating belt is hard to meet the requirement of diverse paper. The authors designed an IH system which could meet the requirement of multi - purpose printing.

Introduction

Due to environmental restriction, lowering the power consumption of electronic devices becomes important. In electrophotographic process, fuser consumes up to 70% of whole energy of the system. Among the power consumption of the fuser, preheating mode which keeps warm the fuser occupied lots of portion, it is needed to reduce or remove the preheating mode. In order to meet the requirement, the way to rapid temperature rising of fuser is essential [1]. Therefore, decreasing thermal capacity of fusing unit members and efficient use of electrical power is important [2]. However, due to the weakness of electro-magnetic field at the end of coil which is caused by horseshoe shape of coil, the temperature of fusing sleeve ends have lower temperature than the center of sleeve. In order to solve this problem, usually fusing sleeve of IH fuser is longer compared to halogen heating type fuser. To overcome this problem, sub coil is used to not for only to erase the electro-magnetic field but also to enhance the electro-magnetic field at the ends of the fusing sleeve.

In this paper, for optimization of IH Fuser, a 3D electro-magnetic simulation is performed and compared with experimental results. The electro-magnetic simulation result is used to predict temperature rising of the fuser.

Electro-Magnetic Simulation

Fig. 1 shows a cross section of IH fuser. The fusing nip is formed between H/R (Heating roller) and P/R (Pressure Roller) and set enough to conduct heat from fusing sleeve to toner. The eddy current which is induced from the electro-magnetic circuit of induction coil and ferrite core heats up the fusing sleeve.

Figure 2 shows layers which form heating sleeve and heating roller. In order to reduce thermal capacity, heat insulation material is located inside of heating sleeve. Therefore, most of the generated heat goes to nip region or remained in heating sleeve, it is possible to achieve rapid temperature rising system. In this study, JMAG studio is used to simulate the electro-magnetic field of IH fuser

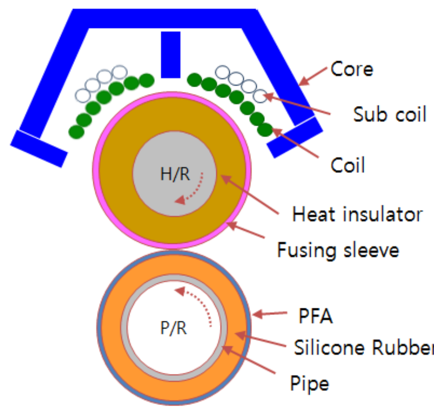


***Fig. 1**. Cross section view of IH fuser*

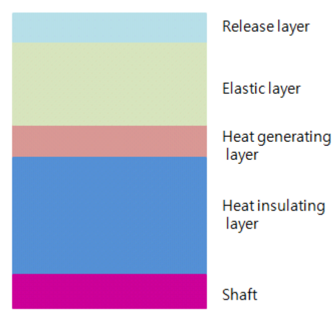


***Fig. 2**. Composition of heating roller*

Figure 3 shows 3D FEM model of IH fuser which is used in this study. Due to the thin layers such as release layer, elastic layer and heat generating layer of heating sleeve, the generated number of elements is too much by automatic mesh. For solving only electro-magnetic problem, the number of mesh is not a big problem. However, to simulate temperature rising characteristic, it needs lots of iteration, the number of mesh becomes critical to solving time. Therefore, in order to reduce the generated number of mesh, the heating sleeve layers, heating roller, pressure roller and fusing nip area are meshed by mapped mesh. Due to the complexity of the shape of coil and ferrite core, inductor parts which are formed by coil and ferrite core are hard to mesh by mapped mesh. Therefore, inductor parts are meshed by automatic mesh and this mesh data is combined with mapped meshed heat roller and pressure roller data.

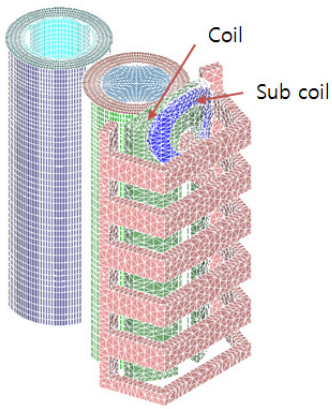
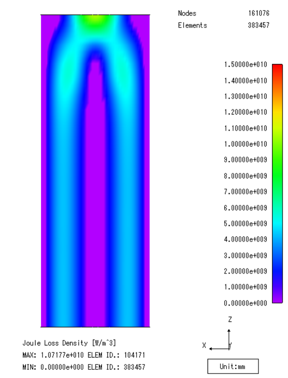
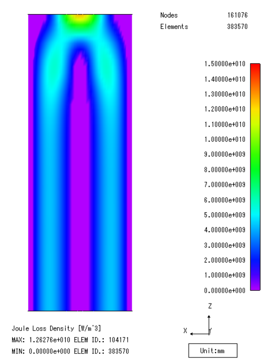


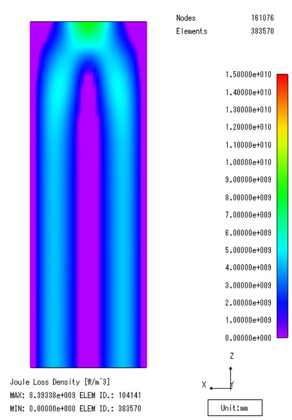
Fig. 3*. 3D FEM model of IH fuser*



(a) No sub coil



(b) Sub coil as enhanced coil



(c) Sub coil as erasable coil

Fig. 4*. Electro-magnetic simulation of sub coil effect*

The real IH fuser is symmetry along the roller length direction, half of the fuser is modeled to reduce calculation time. Figure 4 shows the Joule loss density which is the generated power per unit volume. Figure 4(a) shows the contour of main coil only (no sub coil effect), Figure 4(b) shows the sub coil effect when it is used as enhanced coil and Figure 4(c) shows when the sub coil is used as erasable coil. As shown in Figure 4, the Joule loss density contour is changed along with the direction of current in sub coil. From the contour, the sub coil effect can be figured out easily.

Figure 5 shows temperature distribution along the heating sleeve surface. From this figure the sub coil effect can be figured out. The temperature profiles are obtained by IR Image of the heating sleeve. The ditches of center are due to temperature detecting device, they could be ignored.

Due to the weakness of electro-magnetic field at the edge of coil, the temperature of sleeve edges are lower than center. In order to get uniform fusing quality, the temperature difference along the fusing sleeve should be within 10°C. With main coil itself, the requirement could not be satisfied. When the sub coil is operated in direction of enhancing the electro-magnetic field, the temperature uniformity can be reached to letter paper size. If the sub coil is operated to the direction of erasing the electro-magnetic field of main coil, the uniformity of temperature of heating sleeve is limited to the B5 paper size.

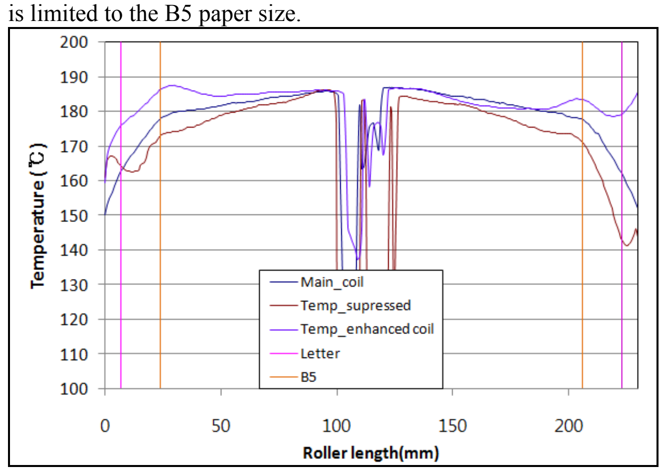


Fig. 5*. Temperature distribution of heating sleeve with sub coil effect*

Heat Transfer Simulation

The simulation tool JMAG could calculate heat transfer characteristic of IH fuser from the calculated heat generation rate of electro-magnetic simulation result. In order to describe the rotation of heating sleeve and pressure roller, virtual motion function of JMAG is used. Figure 6 shows the temperature rising characteristic of IH fuser. Even though there is little deviation between simulation result and experimental result especially at the beginning, overall simulation result is matched well with experimental result.

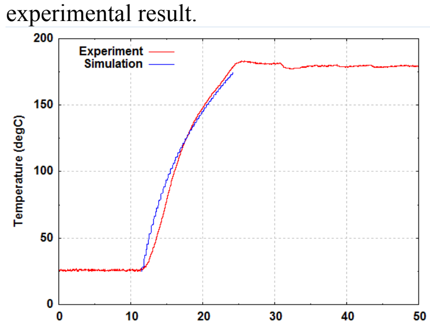


Fig. 6*. Temperature rising characteristic comparison of simulation and experimental result*

Shaft and Magnetic Property of Metal Sleeve Effect

Table 1 shows the effect of shaft material. With changing shaft material from steel to Al (magnetic material to non-magnetic material), it could be possible to suppress heating loss on heating sleeve. Due to the heat insulating material between heating sleeve and shaft, heat generation at shaft could not affect to the temperature rising of heating sleeve. Therefore, even though the penetration of magnetic field to the shaft of heating roller is small, it could affect to the temperature rising characteristic heating sleeve. Thus it is desirable to use non-magnetic material as shaft of heating roller.

Table 1: Shaft material effect

	Joule loss (W)	
Shaft material	Al	Steel
Belt	852.83	833.11
Shaft	4.24	23.26
Total	857.07	856.37

Table 2 shows the effect of shaft diameter. With same input condition, the amount of total heat generation is different according to the diameter of shaft. It was possible to save 2 seconds of rising time to fusing temperature with changing of shaft material from steel to Al and changing shaft diameter from 28 to 26mm.

Table 2: Shaft diameter effect

	Joule loss (W)		
Shaft diameter (mm)	26	28	30
Belt	882.87	833.11	787.26
Shaft	21.13	23.26	29.45
Total	904.0	856.37	816.71

Figure 7 shows the temperature rising simulation result of shaft diameter and shaft material effect. As mentioned in Table 1 and 2, the effect of diameter and material of shaft is verified.

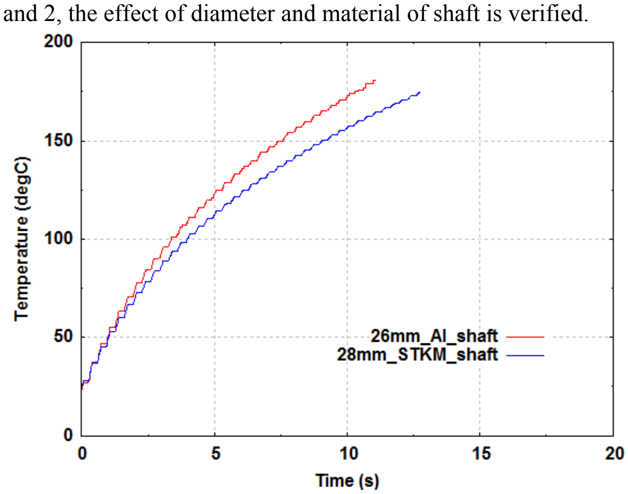


Fig. 7. Effect of shaft material and diameter

As a heating sleeve, Ni is widely used. Ni is a magnetic material with good electrical conductivity. Therefore, when performing simulation, it is common to put magnetic property of nickel as an input condition. However, the generated magnetic field in Ni sleeve is in range of saturated region, the Ni sleeve becomes non-magnetic material [3]. Using the magnetic property of Ni could make error, the saturation range of sleeve material should be checked before the simulation is performed. Table 3 shows electrical and magnetic property of several sleeve material.

Table 3: Electrical and magnetic material property of sleeve

Medium	Resistivity (Ω -m)	Permeability (H/m)
Cu	1.72E-08	1.2566290E-06
Ni	6.99E-08	1.2500000E-04
SUS304	7.2E-07	1.2566290E-06

Table 4 shows the effect of relative permeability of Ni. As shown in Table 4, the simulation result of magnetic material case generate around 50W of more heat at heating sleeve. Therefore relative permeability input value could overestimate the heat generating rate of heating sleeve. Therefore, with magnetic material property of the simulation result could conclude overestimated temperature rising time of IH fuser.

Table 4: Relative material effect

Medium	Relative permeability	Joule loss (W)
Ni	100	959.47
Ni	1	904.0

Conclusion

Using sub coil as enhancement of electro-magnetic field, it could be possible to make flat the temperature distribution of heating sleeve. With this approach it was possible to overcome the weakness of electro-magnetic field at the edge of the induction coil and was possible to shorten the length of IH fuser.

With 3D electro-magnetic field simulation using JMAG, it is possible to predict the effect of sub coil. The 3D electro-magnetic simulation and heat transfer simulation which includes rotation of heat sleeve and pressure roller are performed and compared with experimental results. From the comparison, it could be concluded that combined 3D electro-magnetic and heat transfer model can be used to estimate the performance of IH fuser. With this 3D model, it is possible to predict the temperature rising characteristic of IH fuser. Therefore, the 3D electro-magnetic and heat transfer simulation could save time to optimize developing IH fuser.

References

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Author Biography

Dae Whan Kim received the B.S. and M.S. degrees in precision mechanical engineering from Hanyang University, Seoul, Korea, in 1988 and 1990, respectively and the Ph.D. degree in mechanical engineering from the University of Maryland, College Park in 2007. From 1992 to 2001, he worked at SAMSUNG ELECTRONICS Co. Ltd., where he worked on the research and design of actuators for optical disk drive systems and optical interface systems. Since 2008, he has been working on the research and development of LBP fusing systems at the DMC Research and Development Center, SAMSUNG ELECTRONICS Co., Ltd.

Jin-Han Kim received the BS and MS degrees from Kyungpook National University, Korea in 1999 and 2001, all in Electronics Engineering. From 2001 to now, he has worked as an electronics engineer at Samsung Electronics Co., Ltd. He has been working on the design and programming of FPGA and MCU in electronic circuits. His recent research is focused on the fusing technology in LBP.