Simulation for Various Types of Low Energy Consumption Fuser

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Abstract

First Low Energy Consumption Fuser (following ODF) was marketed by Canon in 1990. In this fuser, we used polyimide film and ceramic heater so that its low thermal capacity enables on-demand printing and energy saving. Most printers produced by Canon are using this technology. Since the market launch , this fuser has been evolved to various types, getting faster and applied to not only monochrome but also to color printers.

Especially many design changes have been made to film. We have been using stainless steel for film base to achieve higher speed and added rubber layer for color printing.

It has been difficult to precisely calculate the effect of these improvements. In this paper, we examine these improvements with simulation.

Introduction

We applied FEM simulator to examine fuser film and heater and found as follows:

1. Rubber layer makes film temperature more even
2. By improving thermal conductivity of polyimide base, we could use it at as higher speed as stainless steel base can achieve.
3. By improving thermal conductivity of polyimide base and rubber layer, we could achieve higher efficiency throughout print pages.

We added rubber layer to get gloss uniformity for color printing[4]. Rubber's small thermal conductivity was obstacle to high speed printing. But we found that rubber layer made heater designing more flexible. Comparing thermal conductivity, we have believed that stainless steel base is necessary to make ODF faster. But it is no longer necessary.

ODF unit and parameters

Figure.1 shows ODF unit, parts and parameters. Fuser film uses polyimide base or stainless steel base. Rubber layer and top layer is applied to the base. In fuser film, there are ceramic heater, film guide and metal stay. Pressure roller is contacting the fuser film and makes nip area.

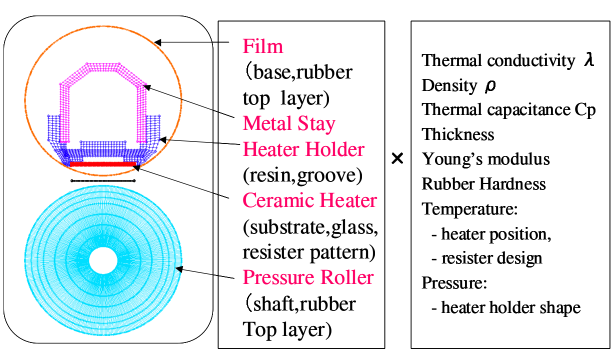


***Figure 1.** Cross view of ODF unit, parts list and parameters*

Structure of Simulator

This model is based on the fuser in Canon LBP-5400.

Basic conditions for FEM model are as follows:

- Helical direction of film: 0.25mm/pitch
- Radial direction of film: 0.01mm/pitch
- Time cycle: 2msec
- Vp=50 or 240mm/sec

And authors used small mesh size for specific area (i.e. heater substrate, heater glass), large size for metal stay and pressure roller shaft. (see Figure 2)

Our simulator is composed of two physical models. One is thermal conducting model which is based on Fourier's Law, and the other is transfer and convection model which is based on Newton's Law. The former is applied to inner area of each part. The latter is applied to contacting area between heater and film, between film and paper, film surface and pressure roller surface.

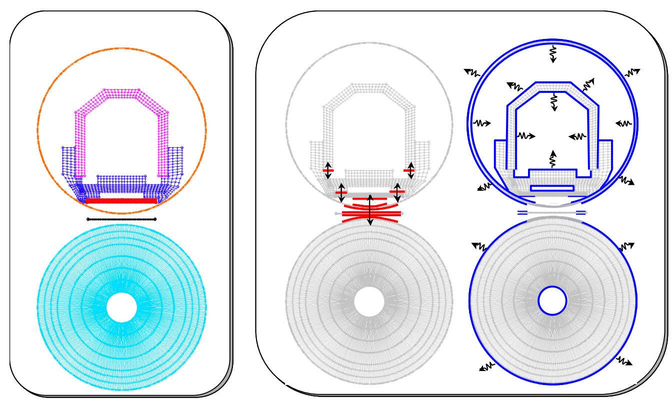


***Figure 2**. Mesh model for FEM*

Other parameters for fusing system are as follows;

- Fusing film diameter 24mm, base thickness 0.05mm
- Pressure roller diameter 25mm, rubber thickness 2mm, PFA tube thickness 0.05mm
- Nip width 7.5mm

Heater structure is shown in Figure 3.

Parameters of heater are as follows;

- Width : 7.38mm,
- Substrate thickness: 0.6mm
- Glass layer thickness: 0.05mm,

Thermister is mounted at the center of heater.

Rubber layer's effect

Rubber layer is necessary for color printing, and its thickness around 0.300 mm is proposed by Uchida et. al [4]. We used 0.275 mm for simulation. Also we used three types of heater as shown in Figure.3.

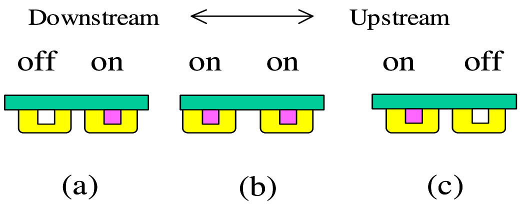
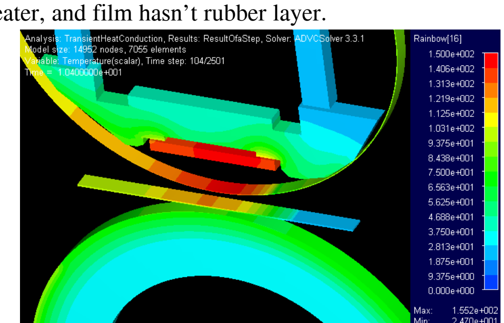


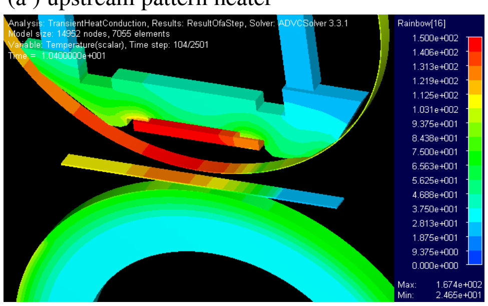
Figure.3 *Three typical models for resister pattern*

Film Without rubber layer

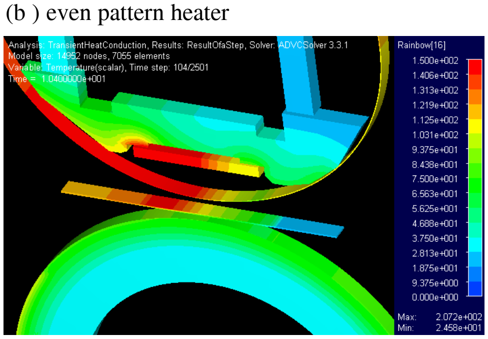
Figure.4 shows contour maps of ODF unit with three types of heater, and film hasn't rubber layer.



(a) upstream pattern heater



(b) even pattern heater



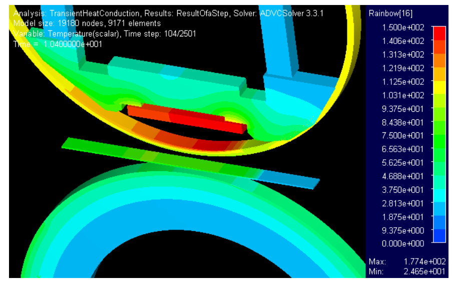
(c) downstream pattern heater

Figure 4. *Contour maps of ODF unit with heater types (a),(b) and (c) respectively (film without rubber layer)*

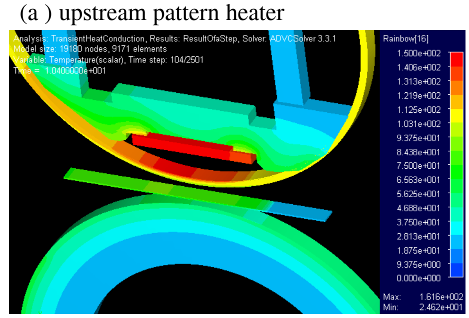
Paper is fed from right side to left side. Figure 4 shows that film temperature with downstream heater (c) is around 40 degrees (C) higher than film temperature with upstream heater(a) at the exit of nip area.

Film With rubber layer

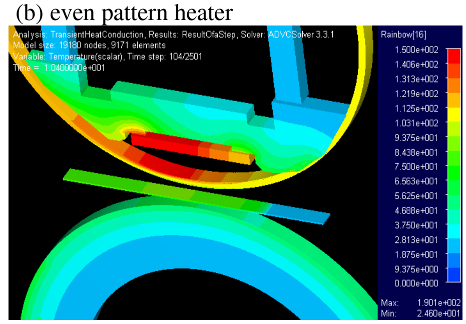
Figure 5 shows contour maps of ODF unit with three types of heater, and film has rubber layer. The film temperature difference is around 10 degrees (C) at the exit of nip area.



(a) upstream pattern heater



(b) even pattern heater



(c) downstream pattern heater

Figure.5 *Contour maps of ODF unit with heater types (a),(b) and (c) respectively (film with rubber layer)*

These results mean that rubber layer reduces the sensitivity to the heater in helical direction.

Sensitivity to ripple of heater resister pattern

Heater has some level of resister pattern ripple, and makes temperature ripple on the surface of film. This ripple causes gloss stripes or poor fixing. We found that rubber layer could reduce the temperature ripple of fuser film. This makes heater designing more flexible. We assumed the gap (low resistance area) 0.25mm in resister pattern as shown in Figure.6, then simulated the temperature distribution of film surface.(see Figure 7)

Figure 7 shows that the temperature difference at gap area is reduced by adding rubber layer.

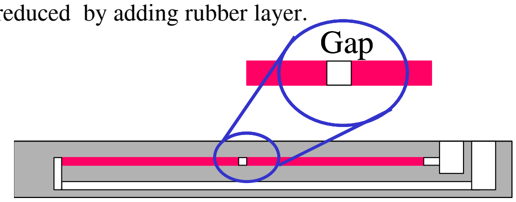


Figure 6. Top view of heater model with the gap in resister pattern

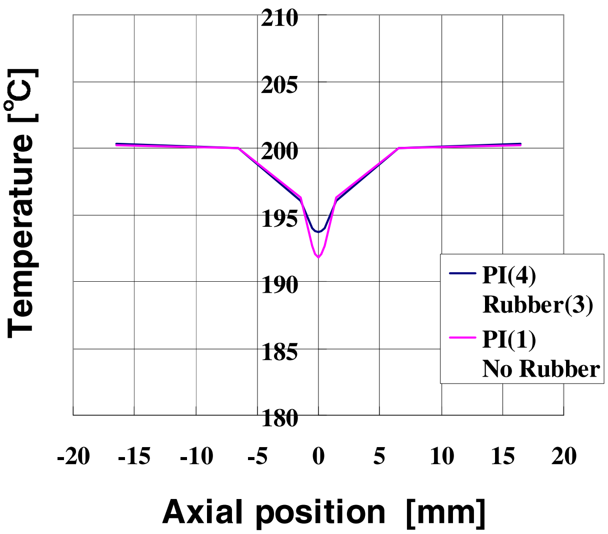


Figure 7. Film surface temperature distribution with gapped resister heater

This result means that rubber layer reduces the sensitivity to the heater in axial direction.

Improvement of polyimide and rubber and their effects

We have been using stainless steel for film base because of its high thermal conductivity, but it takes long time to process. And stainless steel makes stiffer contact to the heater. On the other hand, polyimide was added with filler to improve thermal conductivity, but could not catch up to the stainless steel. Recent improvement of filler technology and mixing technology gives higher thermal conductivity to polyimide and rubber. We will show their effects.

We assumed two constrain conditions as follows:

-necessary energy to fixing is 600J/page.

-temperature of heater backside must be lower than 240℃

latter condition is requirement of film-guide material.

Tabel.1 shows the variation of material which we used in simulation. These level of thermal conductivity λ can be achievable, and is normalized to the reference.

Figure 8 shows that the maximum print speed which is calculated on the former two conditions. In this case, rubber isn't applied to film base. As result, polyimide with adding thermal conductive filler can achieve almost as same speed as stainless steel.

Table 1 Material combination for simulation

Base	λ	Rubber	λ
PI1 (ref)	1	Rubber1 (ref)	1
PI2	2	Rubber2	2.1
PI3	3	Rubber3	2.6
PI4	4		

Figure 9 shows how the print speed depends on the thermal conductivity of rubber and film base. And again polyimide with adding thermal conductive filler can achieve almost as same speed as stainless steel.

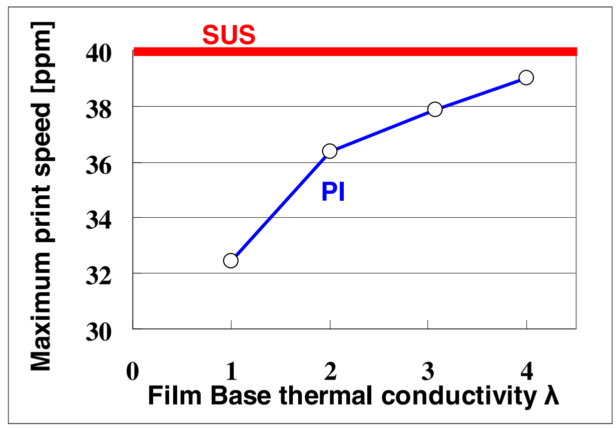
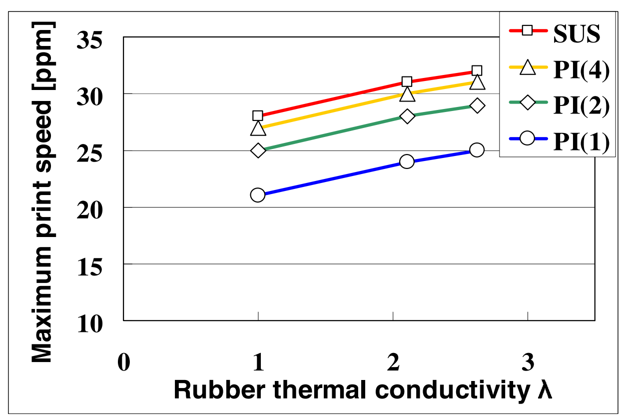


Figure 8. Achievable Maximum Print speed on each thermal conductivity using two constrain conditions. Upper red line shows achievable level with stainless steel base.



Fligure.9 Speed depends on thermal conductivity of rubber and film base.

Comparison of energy efficiency

Figure.10 shows how energy efficiency changes by three types of fuser film. Tested samples are shown in Table 2.

We define energy efficiency q/Q as follows; q is heat flux from film to paper, Q is total heat inputted to heater. Figure10 shows result.

Table 2 Tested film sample

Sample	Film Base/conductivity	Rubber/conductivity	Achievable Speed
1	PI(1) / Low	Rubber(1) / Low	21ppm
2	PI(4) / High	Rubber(3) / High	31ppm
3	Stainless Steel /High	Rubber(3) / High	31ppm

Data is plotted from page 1st to page 20th.

As result we say;

-high thermal conductivity polyimide shows same efficiency as stainless steel shows.

-high thermal conductivity samples show high efficiency from the beginning .

-low thermal conductivity sample shows low energy efficiency at the beginning, but is gradually improved by pages.

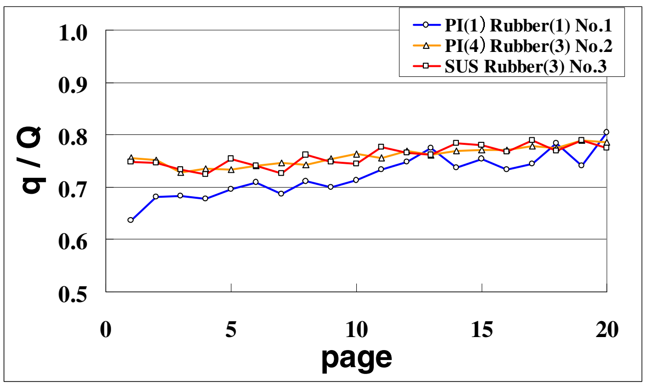


Figure 10. *Energy efficiency of three film types.*

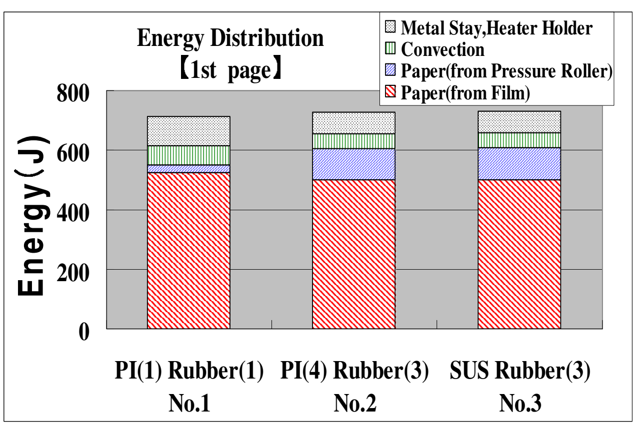


Figure 11.*Energy Distribution of ODF at the 1st page*

We think that high conductivity sample (No.2 and 3) can heat pressure roller sufficiently in warm-up period, so pressure roller can supply heat to paper. Figure 11 shows how inputted energy is distributed in the fuser at the first page. Figure 12 shows how inputted energy is distributed in the fuser at the 20th page.

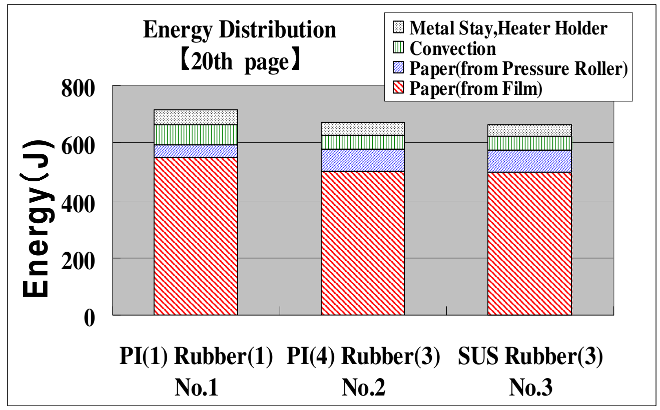


Figure 12. *Energy Distribution of ODF at the 20th page*

Conclusions

Simulation gives us the results as follows;

-By adding rubber layer to fuser film, it allows heater designing to be more flexible.

-Polyimide with improved thermal conductivity could achieve as high speed as stainless steel does

-Improvement of thermal conductivity of rubber and polyimide provides higher energy efficiency to ODF

Summary

We applied rubber layer to film aiming to improve print quality, but it could also widen the designing flexibility. And we have believed that stainless steel is necessary to increase print speed, but it's no longer necessary. We are expecting further improvement of thermal conductivity of rubber and polyimide.

Acknowledgment

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Author Biography

Yasumasa Otsuka received his BS in physics from Kyoto University in 1981. He joined Canon Inc. and has been engaged in R&D of electrophotography.

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