Special Issue on Printers: UDC 772.93.023.73 : [771.74 : 678.7-492.2-408.2]

Encapsulated Toner Fixed by Low Temperature

Toru ISHIHARA*, Kunihiro HAYASHI**, Katsuyuki ITO***, Jun HASEGAWA****

Abstract

We developed a polymerization toner that has an encapsulated structure based on spherical polymerization toner technology which we commercialized before other companies. By using this new toner, fixing at a temperature lower than ever before became possible, and the energy consumption of a printer decreased dramatically, without adding any special structure to equipment in the fixing process. Fixing performance, preservation performance and hot offset resistance, all thermal characteristics required for toner, are in a trade-off relationship. The encapsulated structure of this toner, however, can compartmentalize this relationship, and improve fixing performance without sacrificing preservation performance and hot offset resistance performance.

1. Introduction

Electrophotographic printing is a printing method that excels in energy efficiency, however, the energy consumption of the fixing process makes up most of the energy consumption of the entire printer, which is the bottleneck to increasing speed and downsizing of a printer. To overcome this problem, various technological developments are attempted for both equipment and toner.

Considering toner, we developed a toner that has a fixing performance at a lower temperature than conventional toners. This paper reports on this new toner, which has a double layer structure (capsule) based on a technology that extends our spherical polymerization toner 1) (hereafter single layer polymerization toner) that we released commercially before any other company.

Hereafter this low temperature fixing encapsulated toner is simply referred to as “encapsulated toner”.

2. Conventional toner manufacturing method and problems

Figure 1 shows the conventional toner manufacturing process based on the milling method. In the milling method, resin to be the major component of toner is manufactured from monomer material. This resin is then fused by heating and then an electrostatic charge control agent and coloring agent are added. After mixing resin until these agents disperse evenly, resin is cooled down to become a lump of toner. This lump is milled by a jet mill, and is processed to be toner after the sorting process and the fluidization agent adding process. The milling method, however, has the following two problems with respect to the requirements for printers seen in the current market.

1. Flexibility in designing resin
   As printers become smaller and exhibit high-speed, toner that can fix at low energy and can be preserved under high temperature is demanded. To implement this, it is necessary to cover resin which is easily fused with resin that hardly fuses. However, manufacturing such a toner is impossible with the milling method, so the primary problem of this method lies with inflexibility in designing resin.
2. Sorting process
   Grains of toner manufactured by mechanical milling have a broad distribution of grain sizes, with a considerable quantity of grain either too rough or too fine. To eliminate such grains, a sorting process is required, where 10~30% of grains manufactured by milling are eliminated.

   Finer toner is more in demand now for high resolution printing. Decreasing the average grain size, however, worsens the yield, so the second problem concerns how to prevent a drop in yield which accompanies the decrease in grain size.

3. Designing encapsulated toner

3.1 Design of basic structure

As Figure 1 shows, encapsulated toner is a polymerization toner which is manufactured by dispersing or emulsifying dispersoids (raw material of toner) into a dispersion medium (water). Dispersoids are monomer oils that contain a charging control agent and coloring agent. Toner grain can be obtained by the reaction of dispersoids. The obtained grain is completed as toner after the cleaning, drying and fluidization agent adding processes.

In toner manufacturing by polymerization, no process consumes the enormous energy that is seen in the fixing, mixing or graining processes of the milling method. Sorting is also unnecessary. Therefore is no problem with drops in yield. Since granulation conditions to determine grain size can be widely set in 1 mm to several tens of mm, the polymerization method is suitable for decreasing the grain size of toner, and is also superb economically.

The encapsulated toner that we developed this time has a double layer structure comprised of a core and shell, and is manufactured by the polymerization method and another

* First Research Laboratory, Oki Data Corporation
** Manager, First Research Laboratory, Oki Data Corporation
*** General Manager, First Research Laboratory, Oki Data Corporation
**** Manager, Product Engineering Division, Information Material Department, Zeon Japan

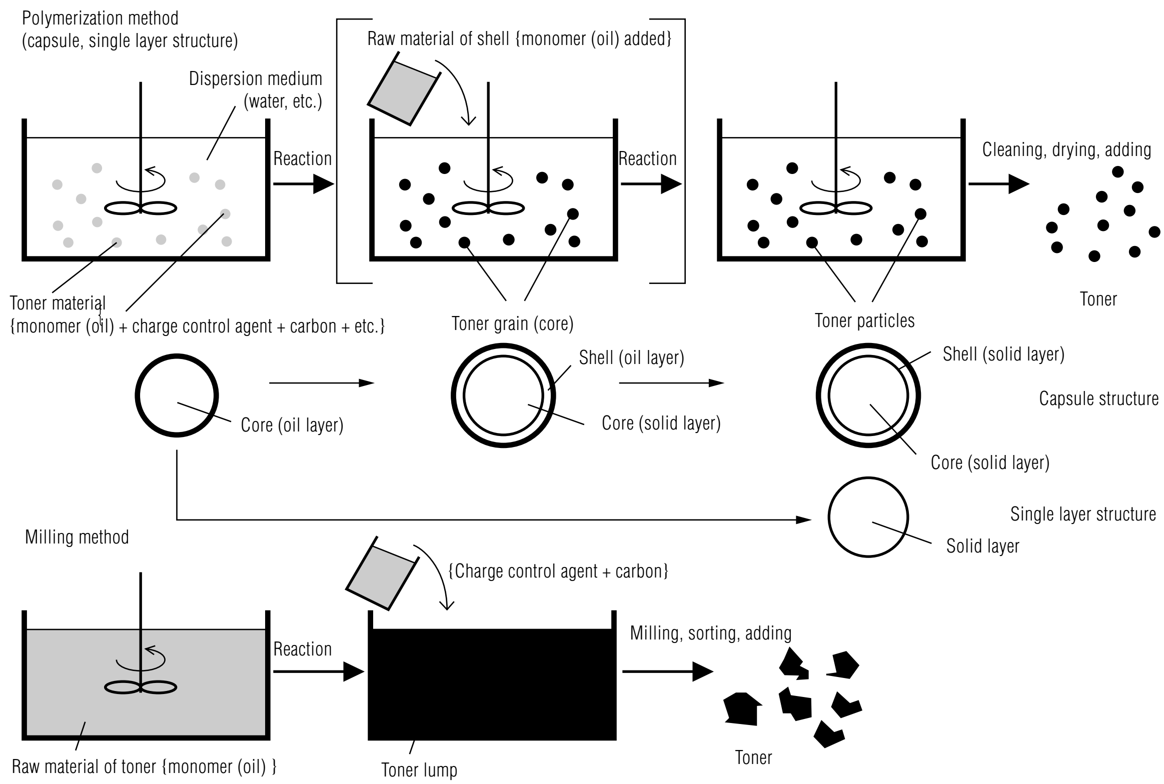

Figure 1: Toner manufacturing process

step that is included in the manufacturing process of single layer polymerization toner. The core grain is manufactured in the same manner as single layer polymerization toner, by the polymerization reactions of oil that is dispersed in the dispersion medium, as described above.

At this point the reaction of single layer polymerization toner is completed.

In the case of encapsulated toner, however, grain obtained here becomes the core to which monomer that will be the shell is added to cause a polymerization reaction of the shell. The processes after this are the same as single layer polymerization toner, which is the cleaning, drying and fluidization agent adding processes.

3.2 Improving fixing performance

The target and characteristics of encapsulated toner are described next. Effective means to improving fixing performance of resin (the main component of toner) are:

1. decreasing softening temperature of resin (the main component of toner)
2. decreasing melt viscosity

Resin with a low softening temperature softens (melts) with low energy, which makes it easier to fix toner at a low temperature. Such toner, however, may generate blocking when placed under a relatively high temperature, such as when under continuous printing.

Blocking is a phenomena where toner is subject to a high temperature softens on its surface and toner particles coagulate. In this status, flowability in the developing unit radically drops, which makes transporting toner to the developing roller difficult or at worst makes printing impossible. In this way, fixing performance and blocking resistant performance are in a trade-off relationship, and in the case of a conventional single layer structure toner, balancing both of these features was difficult.

For encapsulated toner we implemented both of these features to a satisfactory level using resin with a low softening temperature for the core, and resin with a high softening temperature for the shell. For actual development, we made an effort to create a capsule structure with a distinctive separation between shell and core, and at the same time examined how to maintain a capsule structure in actual use preventing the stripping of the shell from the core.

To create a clear boundary between shell and core, compatibility between resin for the shell and resin for the core must be low. This allows clearly separates functions, but also causes problems during usage.

In actual use, toner receives friction from various rollers in the developing unit, and friction caused by such mechanical stress as doctor blades. If the boundary between shell and core is too distinctive (that is, resins have a low compatability and easily separate from each other), then the shell tends to be stripped from the core by the stress. Under such conditions, the core (softening temperature is low) is exposed, which causes such failures as blocking and filming. Filming is a phenomena where the surface of toner is melted by frictional heat, and is fixed on the surface of the developing blade and image drum. If filming occurs, striped patterns appear on the printed face, which deteriorates image quality considerably. As a consequence, the boundary between the core and shell must be clear so that the core and shell can function independently, but at the same time, adhesion (compatibility) to endure mechanical stress is necessary. In actual development, we searched for optimum conditions from both a material and polymerization method point of view, and implemented both the required adhesive strength and compatibility.

Assuming that toner will be fixed with a mechanism that is simple enough not to cause an extra load on the printer, we developed an encapsulated toner based on oil-less fixing, which does not need any additional mechanism for oil replenishment. Because of this, we improved the fixing performance not by decreasing melt viscosity but by decreasing the softening temperature. We also optimized the shell conditions so that the shell prevents blocking but does not drop the fixing performance.

4. Characteristics of encapsulated toner

4.1 Fixing characteristic and preservation characteristic

Figure 2 shows the relationship between the fixing temperature, when the fixing ratio of the toner is 95%, and the critical preservation temperature.

The fixing ratio was determined by the tape stripping method. This means that adhesive tape is attached to the printed surface where the fixing process has completed, it is rubbed with a certain load, stripped, and then the fixing ratio is determined from the ratio of density before and after stripping the tape, as shown in the following formula.

Fixing ratio = density after striping / density before stripping x 100 (%)

The critical preservation temperature is the upper limit of storage temperature which is determined by the measuring degree of blocking by the coagulation degree method after leaving the toner at storage temperature for one month. In the coagulation degree method, sample toner on a screen is vibrated under certain conditions, and the percentage of weight of blocking toner that remains on the screen of the sample toner is calculated. For this experiment, we tested toner not under a natural environment but under a certain pressure considering the pressure that toner receives in the developing unit. The upper limit temperature when the coagulation degree is 2% or less under this conditions was set as the critical preservation temperature.

As Figure 2 shows, single layer polymerization toner and milled toner presented similar results, that is, fixing at a lower

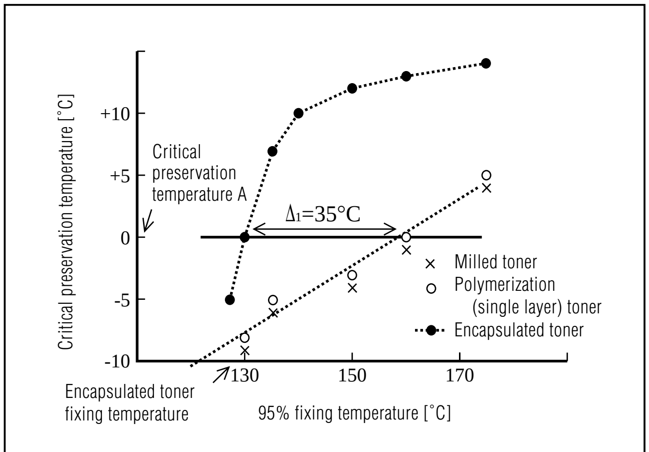

Figure 2: Relationship between fixing characteristic and preservation characteristic

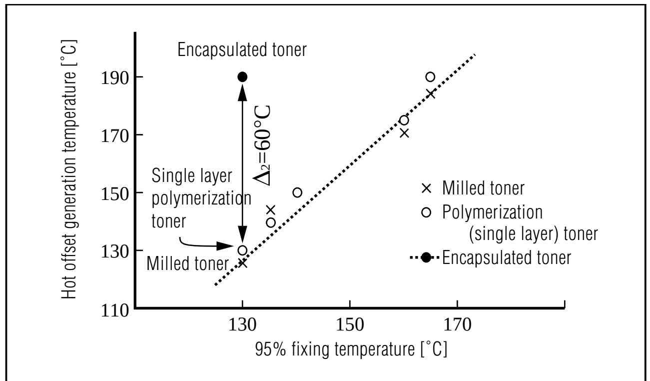

Figure 3: Hot offset characteristic of toner having critical preservation temperature A

temperature decreases the critical preservation temperature.

Encapsulated toner, on the other hand, showed a different result, that is, critical preservation temperature can be increased without increasing temperature for fixing until the shell reaches a certain thickness (for this experiment, we created various samples with the shell thickness as the parameter). The fixing temperature of encapsulated toner that satisfies target critical preservation temperature A is 35°C ($\Delta 1$ in Figure 2) lower than the fixing temperature of single layer polymerization toner and milled toner that have the same critical preservation temperature A. As a consequence, power consumption for fixing can be decreased approximately 30% compared with conventional toner.

4.2 Hot offset characteristic

Figure 3 shows the relationship between the 95% fixing toner and the hot offset generation temperature of various toners that satisfy critical preservation temperature A in Figure 2.

To maintain critical preservation temperature A, an improvement of the fixing ratio of single layer polymerization toner and milled toner was attempted by decreasing melt viscosity without changing the softening temperature of resin.

The 95% fixing temperature of single layer polymerization toner and milled toner, where the melt viscosity of resin has been changed, is closely interrelated to the hot offset generation temperature shown by the dotted line in Figure 3. Single layer polymerization toner and milled toner, which are designed to achieve the the fixing ratio as encapsulated toner, have a low melt viscosity, generating hot offset very easily. At this time, the hot offset generation temperature and 95% fixing temperature are almost the same. Therefore to obtain a hot offset margin similar to encapsulated toner for milled toner and single layer polymerization toner, such a means as attaching a silicon oil coating unit is necessary for the printer.

Encapsulated toner, on the other hand, has a sufficient hot offset margin. Since the fixing performance has been improved not by dropping melt viscosity but by decreasing the softening temperature, an approximate 60°C margin, from 95% fixing temperature to the hot offset generation temperature (Figure 3 $\Delta 2$) is obtained. With this margin, oil-less fixing is easily implemented at a low fixing temperature.

4.3 Dependency of fixing ratio on pressure

Figure 4 shows the dependency of fixing ratio on pressure. In the case of single layer polymerization toner, fixing ratio has a linear increase until it is saturated, but in the case of encapsulated toner, fixing ratio jumps up at a certain value from where the increase becomes very similar to the fixing characteristics of toner with only core. This is because the hard shell breaks at a certain pressure or higher, and the core with a low softening temperature directly contacts the heat roller, which increasing fixing ratio. This result also shows that the shell does not decrease in fixing performance.

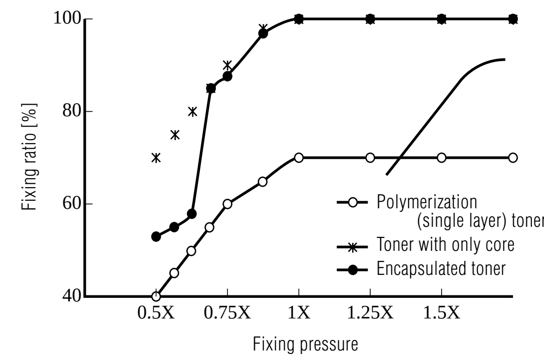

Figure 4: Dependence of fixing ratio on pressure

5. Conclusion

We developed an encapsulated toner based on the polymerization toner technology that Okidata commercially released before any other company. This new toner made it possible to fix at a lower temperature than conventional toner and contributed to decreasing fixing energy. Increasing the speed of the printer without increasing fixing temperature also became possible.

Since encapsulated toner has great flexibility in material design, we will continuously develop this toner aiming at further improvements in performance.

6. Reference

1. Toru Ishihara, Masato Sakai, Toshiro Murano, Katsuyuki Ito: "Toner recycle printing process by polymerization toner," *Oki Kenkyu Kaihatsu,* 166, 62, 2, (1995): 113 ~ 116.