Optimization of Process Condition for Perfect Erasing Machine for Decolorable Toner

Takeshi Gotanda, Satoshi Takayama, Kengo Furusawa, Yumiko Sekiguchi and Kenji Sano; Toshiba Corporation; Kawasaki, Kanagawa/Japan

Abstract

We have developed a perfect erasing technology to erase an image printed on a sheet of paper, with decolorable toner. The decolorable toner has leuco dye colored with developer. Heating discolors the toner due to dissociation of the dye and the developer. A human cannot recognize an image subdivided into pieces and equal brightness image against the background. These facts are known to be an area effect and a Liebmann effect in perception psychology. The image eraser has an erasing process consists of rubbing, dust cleaning and heating. After the process, a trace of the original image, such as a character, cannot be recognized. This method has achieved both complete destruction of information and renewal of the printed paper. We revealed principal factors for the erasing quality and the optimum process conditions. We demonstrated a new concept.

Introduction

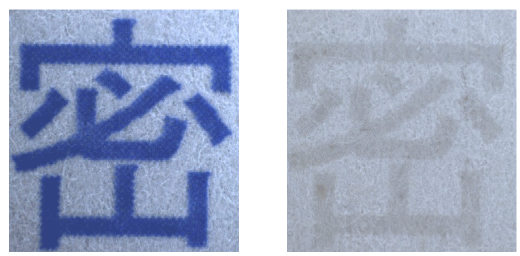
Contrary to expectations that use of computers in offices would lead to reduced use of paper, recent information technology has increased paper consumption for printers and duplicators. Consequently, paper consumption has been recognized as an important environmental problem, which has led to awareness that technology for reusing paper is a possible solution. Reuse technology of paper is relatively effective, because almost all office paper is discarded within a short period. There are several reuse technologies such as toner peeling machine[1)], rewritable paper[2)], photo-fadable toner[3)] and our decolorable (erasable) toner[4)]. Toshiba Corp. has commercialized the decolorable toner named e-blue™ in 2003.

The decolorable toner e-blue™ and handwriting by the decolorable ink can be erased with heating. We have developed and commercialized a heat eraser[5)]. e-blue™ is composed of leuco dye colored by developer. In the decolorizing process, suitable heating cuts the interaction between the dye and the developer, and the dye looses color. The developer diffuses within binder resin, and then it is irreversibly trapped by absorbing material. e-blue™ can be used in the same way as a conventional toner for electrophotographic printing, and moreover, can be erased by heating with a special heat eraser. Consequently, the paper can be used repeatedly.

However, the main content of the toner is resin such as polystyrene. The heat erasing can decolorize the colored dye but cannot erase the resin on a sheet of paper. Therefore, characters can be read as a ghost image after heat erasing. Image samples before and after heat erasing are shown in Fig.1. From the viewpoint of environmental protection, batch heat erasing is the best reuse method because the least energy is consumed. However, from the viewpoint of information security, the heat erasing is inadequate.

Solvent erasing[6)], which is another method of erasing the e-blue™, can erase the decolorable toner perfectly by contact with an organic solvent, such as acetone or dichloromethane. Since such solvents can dissolve the resin of toner, and then the solution is absorbed in to the paper, no trace of the toner remains on the paper. However, as organic solvents are generally toxic and/or flammable, they are unsuitable for use in offices.

We have discovered a perfect erasing method[7)], which is suitable for practical use in offices. In this paper, we focus the rubbing process of the perfect erasing method.



a) original image *b) toner resin (ghost image)*

Figure 1. Image samples before and after heat erasing

Characteristics of Human Eyes

It is difficult for human eyes, that is, the brain, to recognize a figure, when the area of a figure is sufficiently small. This is the Area Effect[8)]. Sufficient area is required for the figure to be recognized by the eye. In addition, it is difficult for the human brain to recognize a figure, when brightness is the same level, even if the color is different. This is the Liebmann Effect[9)]. Sufficiently different brightness is also need in order to recognize a figure. Therefore, when the area of a figure is sufficiently small and brightness is the same level, the human brain cannot recognize the figure. These characteristics of the human eyes are known in perception psychology.

Perfect Erasing Method and New Concept of Shredder

We utilized the above-mentioned characteristics of the human eyes to erase an image perfectly. As shown in Fig. 2, the method consists of three processes: rubbing, cleaning and heating. The microscopic photograph of the image samples, the original image, the image after rubbing, and the image after rubbing and heating, are shown in Fig.3. The rubbing process subdivides and scatters the original image and the heating process reduces the difference in brightness between the character and the paper. The heating process can decolorize the image because the toner is e-blue™. We have also confirmed that neither ultraviolet radiation nor an infrared camera assists an image recovery. Our method can provide a new concept of a shredder, that is, a perfect erasing machine, which achieves complete destruction of information and a renewal of the printed paper.

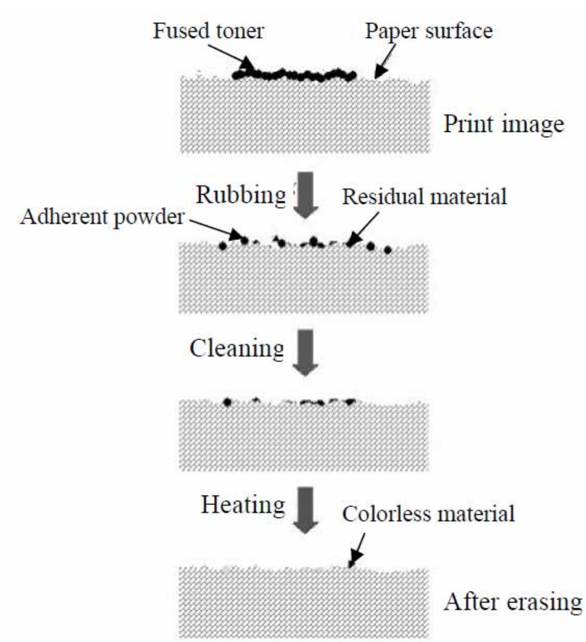
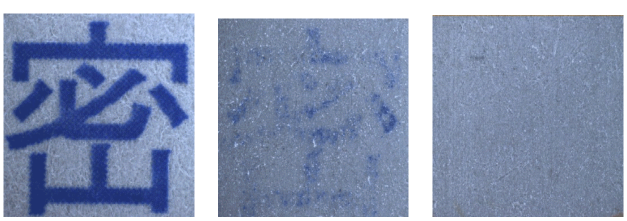


Figure 2. Cross-sectional schematics of a perfect erasing method



a) Original image b) After rubbing c) After rubbing and heating Figure 3. Image samples

Rubbing Machine

To study the process, we developed the rubbing machine, shown in Fig.4. The machine consisted of a paper conveyor roller and a belt sander with a switching mechanism. The rubbing process subdivided an image and scattered shaved toner on the paper surface. The subdividing and scattering process made it difficult for the human brain to reconstruct the image. The sander roller rubbed the surface of the paper on the conveyor roller. The conveyor roller and the belt sander rotated in opposite directions.

The switching mechanism worked to avoid scratching the surface of the conveyor roller by the belt sander in the case that there was no paper on the conveyor roller and to regulate the pressure of the belt sander on the surface of the paper. In this mechanism, there was a pushing roller at a backside of the belt sander, which pressed the belt sander to paper. The pressure could be controlled by hardness of the roller.

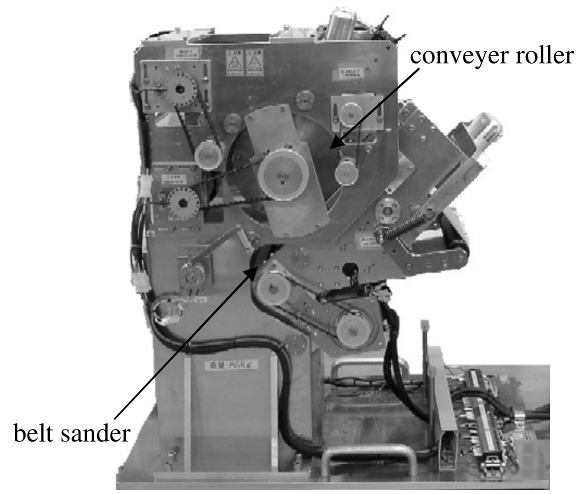


Figure 4. Rubbing machine

Stabilization of Quality

We have found a problem, that is, instability of the image density after rubbing. Our target value for image density after rubbing is 0.1, because the image density is not recognized by human eyes when the image is erased by heating. We tested stability of the image density with a test chart consisting of characters of 10～18 points. The image density was measured with CR300 (Konica Minolta Sensing, Inc.) Fig. 5-a)-left shows the change of the image density after rubbing. We controlled the parameters as follows: roughness of the belt sander was P400[10], hardness of the pushing roller was 15 IRHD (International Rubber Hardness Degrees)[11], and velocity of the conveyor roller was 6 m/min. Velocity of the belt sander was controlled to obtain the target value. Fig. 5-a)-left shows that the image density increased, although a brush swept dust on the belt sander. In Fig. 5-a)-left, marked point means that we cleaned surface of the belt sander manually with a vacuum cleaner. Although we cleaned the belt sander periodically, we obtained the target value of the image density up to the 200th sheet of paper.

We found that high-speed rotated belt sander caused an air stream at surface of the belt sander as shown in Fig. 5-a)-right. The air stream carried the dust, and then dust adhered to the surface of the paper. Because the dust covered paper, the image density after rubbing was unstable.

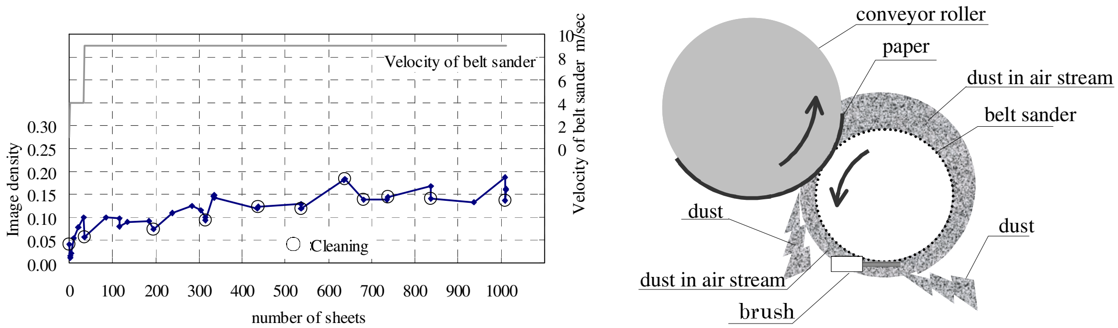
Then, we equipped the surface of the belt sander with a blade to cut the air stream that carried the dust. As shown in Fig. 5-b)-left, although the image density after rubbing could not be stabilized, it was almost 0.1 to about the 800th sheet of paper without manual cleaning with a vacuum cleaner. After the test, when we cleaned the belt sander, image density was 0.1 after rubbing. Consequently, due to increase of the accretion (dust), this dust removal method was insufficient.

As shown in Fig. 5-c)-left, the combination of the brush and the blade effected the image density of 0.1 after rubbing. This dust removal method stabilized the image density after rubbing to the 1000th sheet of paper. We estimated that this method has a synergy effect of the brush and the blade as show in Fig. 5-c)-right. The function of the brush was not only the cleaning of an accretion; it scattered the accretion into the air stream, because the tip of the brush vibrated due to uneven surface of the belt sander. Finally, the blade cut the air stream that contained dust. Therefore, the dust removal method that consisted of brush and blade stabilized quality of the rubbing.

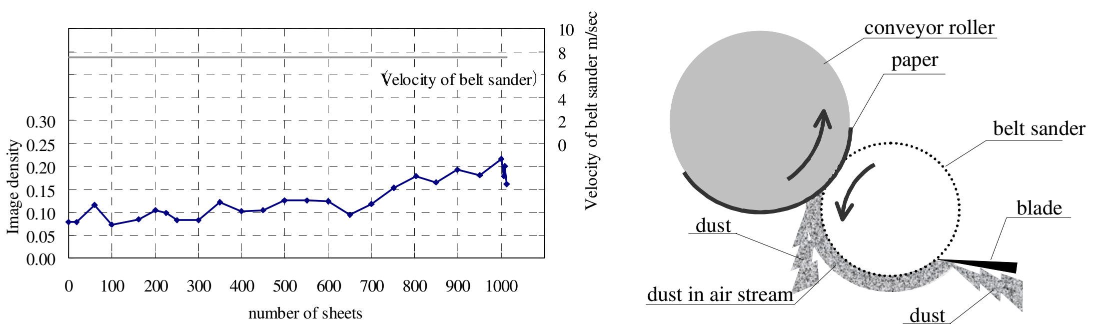
Optimization of Parameter

We clarified the suitable process conditions to obtain the target value. In the case of 6 m/min velocity of the conveyer roller, 3 m/sec velocity of the conveyer roller and 15 IRHD hardness of the pushing roller, the change of image density is plotted against roughness of the belt sander as shown in Fig. 6-a). Roughness of the belt sander was P320, P400, P600, P800 and P1000. These belts are commercially available. When the roughness of the belt sander was P400, image density after rubbing was less than 0.1. In the case of P320 roughness, the conveyer roller dropped paper because of high- friction.

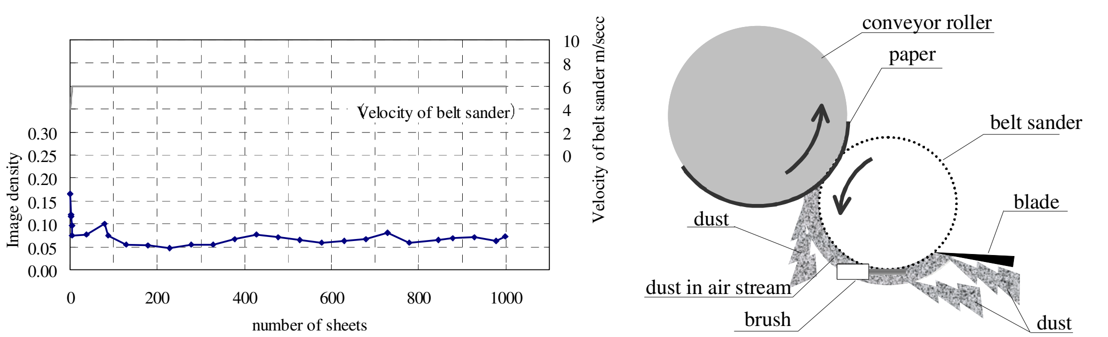
In the case of three velocities of the conveyer roller, the image density after rubbing is plotted against velocity of the belt sander as shown in Fig. 6-b). In this case, roughness of the belt



a) brush

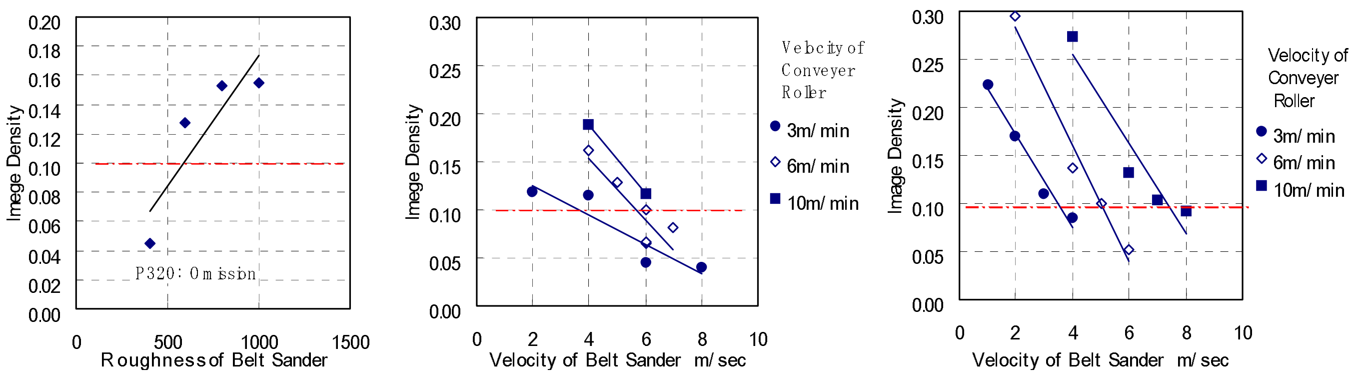


b) blade



c) blade and brush

Figure 5. Change of image density for each dust removal method



a) Roughness of belt sander
-Velocity of belt sander: 6m/sec
-Velocity of conveyer roller: 3m/sec
-Hardness of pushing roller: 15 IRHD

b) Velocity of belt sander and conveyer roller in the case of 15 IRHD hardness of pushing roller
-Roughness of belt sander: P400

c) Velocity of belt sander and conveyer roller in the case of 30 IRHD hardness of pushing roller
-Roughness of belt sander: P400

Figure 6. Change of image density after rubbing in the case of several parameters

sander was P400 and hardness of the pushing roller was 15 IRHD. The faster the velocity of the conveyer roller, the faster was the velocity required for the belt sander, due to increasing the polishing amount per unit time.

In addition, in the case of that hardness of the pushing roller was changed to 30 IRHD, the image density after rubbing is plotted against velocity of the belt sander as shown in Fig. 6-c). The image density after rubbing was 0.1 at relatively low-velocity of the belt sander and the conveyer roller, against 15 IRHD hardness of the pushing roller. However, there was a part with heterogeneous image density due to nonuniform rubbing. That was caused by nonuniform pushing force by the nonparallel pushing roller and conveyer roller. We have regulated the hardness of the pushing roller to solve this problem.

Long-Term Stability

Based on the results above, we have established the long-term stability of the erased quality. Then, we used the dust removal method consisting of brush and blade and the optimum conditions (roughness of the belt sander: P400, hardness of the pushing roller: 15 IRHD. In addition, we controlled the velocity of the belt sander and conveyer roller to obtain 0.1 of the image density after rubbing, as shown in Fig. 6-b).

As a result, the rubbing machine worked continuously to the 3500th sheets of paper without manual cleaning. Throughput of a usual shredder is about 200 sheets of paper. In short, the rubbing machine worked about 17.5 times more the usual shredder without maintenance.

Conclusion

The perfect erasing method consists of rubbing, dust cleaning and heating. This method achieves both complete destruction of information and renewal of the printed- paper. However, rubbing process had a problem, namely, unstable quality of the image density after rubbing. Our dust removal method and an optimized parameter realized long-term stability of the quality. With this technology, we have realized the perfect erasing machine.

References

[1] K. Murohoshi, Y. Hosada, USP 5,846.682.
[2] K. Tsutsui, T .Yamaguchi, K. Sato, Jpn J.Appl.Phys., 33, pp.5925-5928 (1994).
[3] H. Kitazawa, S. Kimura, E. Kawamura, T. Kawanishi, USP 5,738,759.
[4] S. Takayama, S. Machida, N. Ikeda, and K. Sano, IS&T's NIP15: International Conference on Digital Printing Technologies, (IS&T, Springfield, VA, 1999) pp.323-326(1999).
[5] S. Takayama, N. Ikeda, T. Gotanda, K. Sano, 2005 Beijing International Conference on Imaging, preprint of extended abstract, (CSIST, Beijing, China, 2005) pp.14-15 (2005).
[6] K. Sano, S. Machida, S. Takayama, USP 6,277,208B1.
[7] S. Takayama, T. Gotanda, K. Furusawa, and Kenji Sano, J. Imaging Sci. Technol. (in press)
[8] E. G. Wever, Amer. J. Psychol. , 38, pp.194-226 (1927).
[9] S. Liebmann, Psychol. Forsch. , 9, pp.300 -353(1927).
[10] ISO25100, JISR6251
[11] ISO48, JISk6253

Biography

Takeshi Gotanda is a scientist at Corporate Research & Development Center, Toshiba Corporation. He received the bachelor of engineering (mechanical) degree from Shibaura Institute of Technology in 1998. He joined Toshiba in 1992 where he has been engaged in R&D of environmental technology. He studied ground pollution and developed "Geo-steam method" for dioxin/PCB-contaminated soil. His current research interest is decolorable toner. Toshiba commercialized the decolorable toner "e-blue" in 2003.