Uncertainty in Evaluation of Accelerated Ozone Fading Tests of Inkjet Prints

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Abstract

Influences of various test conditions, such as ozone concentration, relative humidity, temperature and gas-flow rate in a test chamber, on an accelerated ozone fading test with various ink-media combinations have been studied. The influences of relative humidity and temperature have been different with each ink-media combination. About ozone concentration, some ink-media combinations have shown reciprocity failure between ozone concentration and duration of exposure. And furthermore, the extent of the influence of gas-flow rate and that of temperature has been different with each ink-media combination. In some ink-media combinations, the influence of gas-flow rate has been larger than that of temperature, while opposite results have been observed in another ink-media combinations.

Introduction

Recently, remarkable progress of printer, ink and media have enabled to make high quality inkjet prints, and the image qualities such as color reproduction, tone reproduction, gloss, sharpness and graininess have reached to the same level as conventional photography. And now, image durability of inkjet print has attracted great deal of public attention. Light fading and gas fading are issues of image stability of inkjet prints. Especially, ozone fading, which is a typical gas fading, is a unique phenomenon of inkjet porous media.

Generally, evaluation of image durability requires a long period, so, various severe test conditions are employed to reduce the test period. However, the estimated lifetime through the accelerated fading test does not always correspond to the actual one, and sometimes it reaches a wrong conclusion on evaluation of a certain media and ink. In case of light fading, high power fluorescent light or xenon arc light is employed to accelerate testing. Usually, accelerated test is carried out with 100 to 300 times higher power irradiation than normal display condition. Some examples of reciprocity failure on light fading tests were reported.[1,2] And the effect of humidity on light fading was also studied.[3,4]

In case of gas fading, for instance, Thornberry et al. and Berger et al. indicated that there was no reciprocity failure in ozone concentration and accelerated ozone fading test represented actual fading.[5,6] However, Bugner et al. indicated that some ink-media combinations showed reciprocity failure.[7] While the ozone concentration in air is very variable in area and season, and the average concentration is the order of ppb, the ozone concentration in the accelerated test is usually employed by ppm order, and gas containing high concentration of ozone blew on test samples. These differences of ozone concentration and gas-flow rate as well as temperature, humidity, and ozone generating mechanism, may cause the discrepancy between accelerated fading test and actual fading. The main objective of this study is to investigate the influences of various test conditions on an accelerated ozone fading test with various ink-media combinations and to point out the problem which should be solved in order to estimate an exact lifetime.

Experimental

Materials

In this study, three kinds of inkjet printers (A-C) and five kinds of porous type inkjet media (A-E) were used, which were commercially available in Japan. The features of media are listed in Table 1. All printers employed dye inks supplied by the printer makers. The test patches consisted of Y, M, C and Gray patch were printed by using all combinations of printers and media. Test prints were dried over 24 hours under 23° C 55% RH.

Table 1. Inkjet Media and Printer Used in this Study

media	filler	Base
A	SiO_2	RC paper
B	SiO_2	RC paper
C	SiO_2	RC paper
D	Al_2O_3	RC paper
E	Al_2O_3	Paper Base

Methods

A commercial ozone testing chamber Model OMS-HS, produced by SUGA TEST INSTRUMENTS Co., Ltd, was used for accelerated ozone fading tests. Ozone was generated from air by corona discharge method. Test conditions were selected from the combination of temperature, ozone concentration, relative humidity and wind-shield shown in Table 2.

Table 2. Test Conditions

Temperature (℃)	Ozone Concentration (ppm)	Relative Humidity (%RH)	Wind Shield	Light
23	0.08	20	used	dark
	0.4	40		
40	2		not used	
	10	60		

In order to examine an influence of gas-flow rate on print surface, a wind-shield was set into the chamber and two test prints were put into the chamber at the same time in such a way that one was set at the side of wind-shield and the other was set under the wind-shield. The test prints were mounted on a piece of card, and fixed at two points (top and bottom). Test prints were taken out from the chamber at regular interval, and the densities of pure color CMY patches were measured with GretagMacbeth Spectrolino to quantify the density loss.

Results and Discussion

The Effect of Relative Humidity

Figure 1 shows the result of the effect of relative humidity. Similar to the previous report,[6,8] dye fading speed is faster under higher relative humidity.

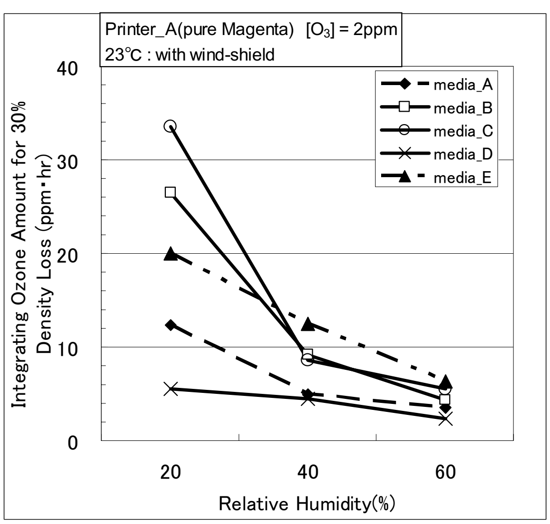

Figure 1. The effect of relative humidity on ozone fading.

However, the degree of the influence of relative humidity is different in each ink-media combination, and the difference is large at low relative humidity. The change of relative humidity sometimes causes the change of ranking of ozone fastness in some ink-media combinations. Therefore, we believe ozone fading test should be carried out at plural humidity points or at least testing humidity condition should be fully discussed.

The Effect of Temperature

Figure 2 shows the result of the effect of temperature. Increase of temperature causes the increase of the rate of dye fading in most of ink-media combinations. The gain of the rate of dye fading with 17°C difference (from 23°C to 40°C), is up to 70%. On the other hand, some ink-media combinations show little temperature dependence on the ozone fading.

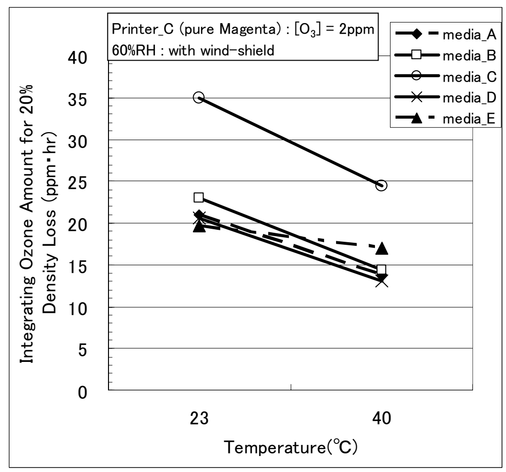

Figure 2. The effect of temperature on ozone fading.

The Effect of Ozone Concentration

The results of the effect of ozone concentration on an accelerated ozone fading test are shown in Figure 3(a) and Figure 3(b).

There is little ozone concentration dependence and the fading behavior conformed to the cumulative amount of ozone exposure shown in Figure 3(a). On the other hand, considerable ozone concentration dependence is observed in the case of Figure 3(b). If the lifetime is determined at 30% density loss, ozone concentration causes 50% difference. The degree of reciprocity failure between ozone concentration and exposure time was different in each ink-media combination.

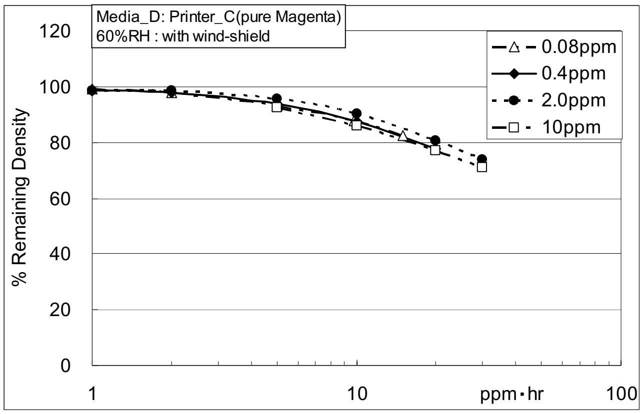

Figure 3(a). The effect of ozone concentration on fading.

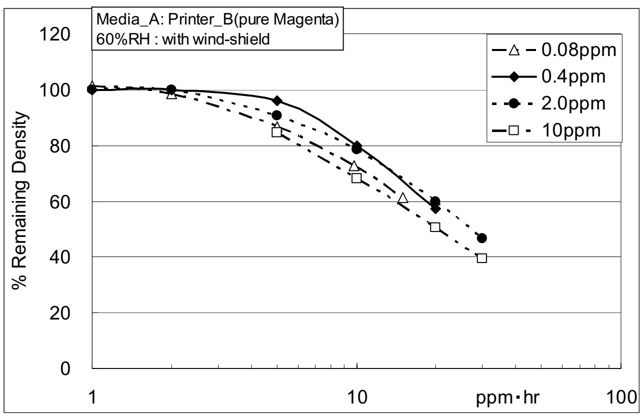

Figure 3(b). The effect of ozone concentration on fading.

This reciprocity failure tended to be observed at low relative humidity. Different results were reported in the previous papers whether the reciprocity failure exists or not.[5-7] We consider that the effects of ink-media combination, ozone concentration, humidity etc. should be investigated more precisely.

The Effect of Gas-flow

Figure 4(a) and 4(b) show the effect of gas-flow. In this study, some ink-media sets were influenced by gas-flow in the ozone chamber.

Figure 4(a) shows a typical result of the influence of gas-flow. The fading behavior which was observed with gas-flow shielding condition is slower, especially at an initial stage, than that of under without shielding condition. In addition, the effect of gas-flow was remarkable under high relative humidity. Note that the influence of gas-flow is larger than the influence of temperature in the case of Figure 4(a).

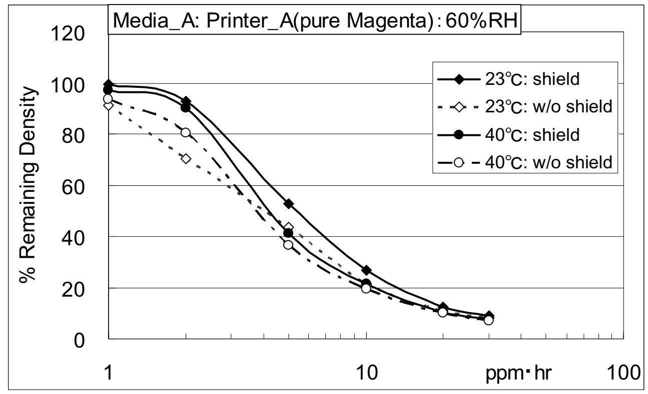

Figure 4(a). The effect of gas-flow on ozone fading.

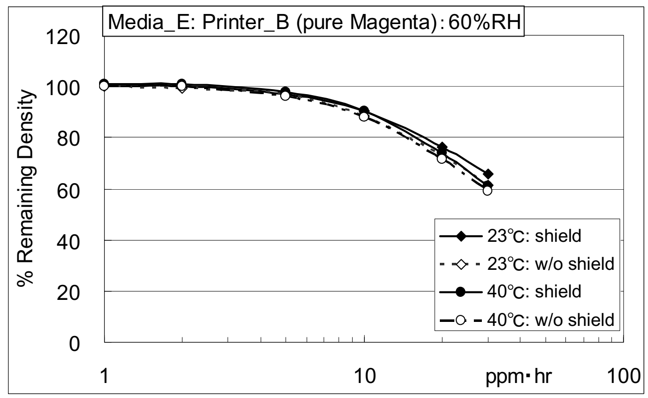

Figure 4(b). The effect of gas-flow on ozone fading.

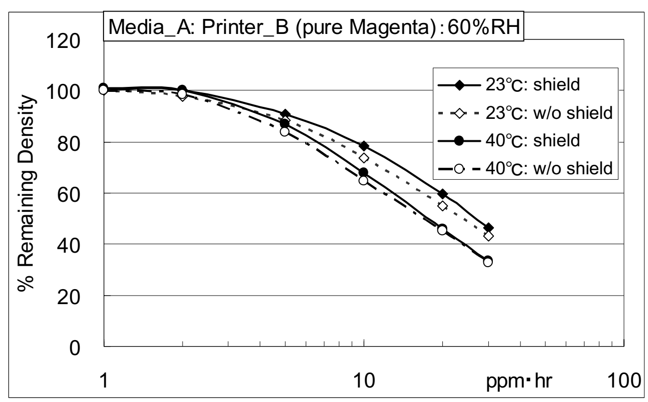

Figure 4(c). The effect of gas-flow on ozone fading.

In the case shown in Figure 4(b), the influence of gas-flow is slightly recognized, which is smaller than the influence of temperature, though the same media was used as Figure 4(a). In addition, when the media was replaced, the influences of gas-flow and temperature almost disappeared as shown in Figure 4(c).

As mentioned above, the ink-media combination shown in Figure 4(a) and that shown in Figure 4(b) exhibit different dependence on temperature and gas-flow. We think that these results suggest the participation of two processes, that is, ozone diffusion into a media and reaction of ozone with imaging dye. In the former case, ozone diffusion process is regarded as a rate-determining step. It is thought that increasing the gas-flow rate onto print surface seems to accelerate ozone supply and dye fading reaction. In the latter case, the reaction of ozone with imaging dye is regarded as a rate-determining step. It is thought that ozone supplying into the media is enough, and increasing the temperature accelerates the dye decomposition reaction. We think that relatively weak gas-flow limits the ozone supplying, and the rate of dye fading is limited by diffusion of ozone into media, and in the course of increasing the gas-flow rate, the rate-determining step will be changed to the process of ozone reaction with imaging dye.

In this study, because of the structure restriction of the ozone testing chamber, the ozone fading tests have been carried out under only two gas-flow conditions. More precise study about the influence of gas-flow will reveal the mechanism of ozone fading. Usually, the gas-flow on an actual displayed print seems to be very weak in comparison with that in accelerated ozone fading test. Therefore, the comparison of the estimated lifetime of some ink-media sets, which have different dependence on gas-flow, may sometimes lead to wrong results.

So we believe that at an accelerated ozone fading test, which is attempted to accelerate an actual fading phenomenon, it is important to investigate the influences of various test conditions, especially that of gas-flow rate, and to select appropriate combination of them.

Conclusion

The influences of various test conditions, such as ozone concentration, relative humidity and gas-flow rate in a test chamber, on an accelerated ozone fading test with various ink-media combinations have been studied. The influences of relative humidity and temperature were different with each ink-media combination. About ozone concentration, some ink-media combinations showed reciprocity failure between ozone concentration and duration of exposure. This reciprocity failure was remarkable at low relative humidity. And furthermore, some ink-media combinations were remarkably affected by gas-flow in a test chamber. We believe that these results suggest the participation of two processes, that is, ozone diffusion into a media and reaction of ozone with imaging dye. In some case, ranking of ozone fastness was changed by these test conditions. So, for estimation of lifetime by an accelerated ozone fading test, it should be necessary to investigate influences of various test conditions and to select appropriate combination.

References

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Biography

Kazuhiro Miyazawa received his master degree in organic chemistry from the Niigata University in 1988. He joined Konica Corporation the same year, and, since then, has been engaged in the research and development of color photographic materials and inkjet materials.