Functionality evaluation of airflow systems for scattered toner dust in a copy machine

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Abstract

Scattered toner dust is a well-known problem in copying and printing machines using the electro photographic development process. The collection of toner dust by forming airflow in order to capture the dust with filters placed at fans was investigated. Specifically, system selections of airflow, which can effectively collect toner dust, were analyzed. In recent research, a conflict was found where forming airflow for collecting toner dust would generate more scattered toner dust. In other words, to avoid problems of such dirt in copy machines caused by toner dust, it is necessary to solve this conflict simultaneously. Therefore, a method for evaluating functionality of an airflow system was proposed. This method can evaluate the collection and restraint of toner dust with one index. By using this method, two airflow systems that have completely different concepts for collecting and suppressing toner scatter were evaluated. As a result, it was found that an airflow system with the concept of forming airflow clearly around developing units is better for collecting toner dust. Furthermore, it was clarified that this result is based on a mechanism of sedimentation adhesion of scattered toner by an influence of gravity.

Introduction

One of the major technical issues in developing a copying and printing machine using a xerography process is how to design an airflow system to handle both heat and toner dust in the machine [1]. Generally, a strong airflow is suitable for cooling. But it is not suitable for collecting toner dust because it causes scattering of the toner dust. If the airflow system is not designed properly, it causes a malfunction due to adhesion of dirt on a sensor device with scattered toner dust.

In recent years, customers have demanded downsizing, high performance and high speed of copying and printing machines. These demands have resulted in a situation where heat generators, such as motors, power supply and fusing units, are forced into a narrow space, so it becomes more difficult to manage the abovementioned interaction between cooling and collecting toner dust. Specifically, it is difficult to install ducts for cooling and collecting due to costs and internal space. It is considered that cooling behaves monotonically with respect to air quantity; however, we have found a conflict such that airflow for collecting toner dust generates more scattered toner. In other words, to avoid problems caused by toner scatter, we have to develop a new airflow system to be able to simultaneously collect the toner dust and reduce its scattering. Thus, we propose an evaluation method for the performance of an airflow system. This method is based on an operating window (Clausing 2004) [2, 3]. It can evaluate the efficiency of both collection and restraint of toner dust with one index.

In this paper, in addition to the proposal and results of the evaluation index, the mechanism of sedimentation adhesion of the scattered toner is also discussed.

Proposal of the functionality evaluation method

Relationship between scattering and collection of toner dust

To collect toner dust efficiently, airflow with high velocity must be created around developer units (a scattering source). However, there is the concern that the amount of scattered toner is increased by forming airflow. We thus conducted a simple experiment to find the relationship between wind velocity and the amount of scattered toner dust. Results are shown in Figure 1.

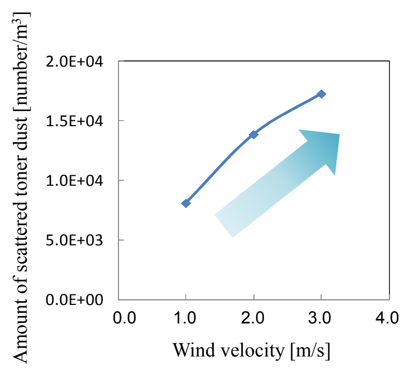

***Figure 1**. Relationship between the amount of scattered toner dust and wind velocity*

These results show that the amount of toner dust increases as wind velocity increases. In order to prevent machine dirt and erroneous operation of sensors caused by the scattered toner dust, it is necessary to control scattering and collection of toner at the same time. Therefore, we proposed an evaluation index of airflow systems that can be described based on only one index, to determine the functionality of airflow systems.

Evaluation method of functionality of airflow systems

As mentioned above, we found a conflict that airflow for collecting toner dust generates more scattered toner dust. In order to avoid problems caused by scattered toner, we have to solve this problem. Scattered toner is generated through magnet roll operations in developing devices, even when there is no airflow. Also, based on the results shown in Figure 1, the amount of scattered toner dust increases as more airflow is formed. In other words, there is an increasing relationship between the amount of toner and air quantity. Similarly, there is also an increasing relationship between the amount of collected toner dust and air quantity. With respect to these characteristic values, the scattering amount is standardized by the amount of scattered toner when airflow has not been formed, and by making the collection amount a ratio in relation to the total amount of scattered toner dust, both values were handled as the rate of increased toner scattering and the rate of collection of toner dust, respectively (Figure 2).

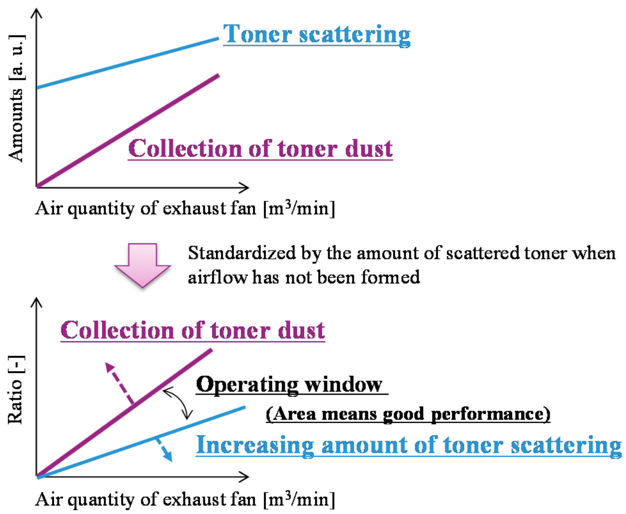

***Figure 2**. Concept of evaluation of collecting and restraint of toner using one index.*

Thus, for any development system, it is possible to determine the amount of increase of scattered toner, and how much of the total amount that was scattered can be collected using an airflow system. Also, it is dependent on the direction in which the operating window is opened up, or in other words, the smaller the scatter increase rate and the larger the collection rate, the better the airflow system.

Here, the collection amount was defined as the change in weight of the filter installed in fan units. The scattered amount is defined as the sum of the total amount of toner scatter that had adhered to the experimental equipment and the filter collection yield. The experimental equipment consisted of an engine that had been removed from the marking unit of a copying machine.

Experiment

Proposal of two airflow systems with different concepts

Subsequently, we tried to apply this evaluation method to two airflow systems that have different concepts. One does not form airflow around the developing apparatus (Airsys1), in order to suppress the increase of the amount of scattering. Another creates airflow that passes through the apparatus, from the inlet to the outlet (Airsys2), in order to collect the scattered toner dust efficiently. These systems were tested on simulation models with computational fluid dynamics (CFD). Each system has an air generator simulating a fan, and we calculated the airflow formed by the fan (Figure 3).

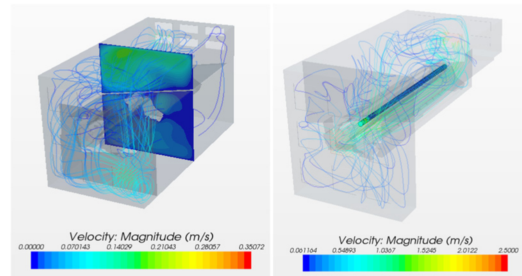

***Figure 3**. Images of Airsys1 and Airsys2 (Using computational fluid dynamics)*

Each of these airflow systems has different control parameters since the concepts are different. Therefore, we evaluated these airflow systems after optimizing them by parametric study.

From their concepts, it is desired for Airsys1 to have large effective air volume around the developing device. Similarly, in Airsys2, it is desirable for the wind velocity near the developing nip to be large. Thus, we chose control factors that satisfy these concepts, and examined a parametric study on orthogonal spaces using CFD. Specifically, we investigated the best levels more to satisfy the concept for each of two airflow systems described above. Results were used as experimental conditions for functional evaluation of collection of toner dust.

The results of the parametric study are shown in Figure 4.

***Figure 4**. Functional effect diagram of airflow systems (Top: Airsys1, Bottom: Airsys2)*

Figure 4 shows the functional effect diagrams of Airsys1 and Airsys2. Airsys1 satisfied the concept of a larger effective air quantity being more desirable; similarly, Airsys2 showed that it is more desirable for the wind velocity near the developing nip to be larger. As expected, for Airsys1, effective air quantity increased as inlet wind velocity became larger, and for Airsys2, by reducing the volume of fluid pass, the wind velocity near the development nip increased in a way that mimicked installation of ducts. The best conditions that were determined from the functional effect diagrams were adopted as experimental conditions for collecting toner dust.

Experiment method

The subject of experiments was one part of the engines (one marking unit) of copying machines (Figure 5). One marking unit is composed of a developer unit, photoreceptor, and intermediate transfer belt.

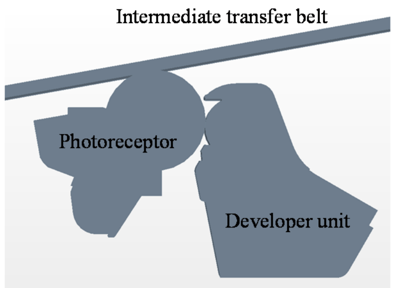

***Figure 5**. Image of subject of experiments (one marking unit)*

Then, we enclosed this experimental device inside transparent acrylic plates, and made openings on the front and rear sides. The transparent acrylic plates enabled us to visualize airflow. An exhaust fan was placed at the opening on the rear side, and a filter to capture the toner dust was installed.

The developer unit was operated for 15 minutes, and then the amount of scattered toner dust was measured by gathering the accumulated toner dust and adding weight changes of the filter. Similarly, the amount of collection of toner dust was measured by the weight changes of the filter.

We compared the performance of the two airflow systems in collecting the scattered toner dust by using the selected best conditions for each as shown in Figure 4.

The parameter diagram shown in Figure 6 is the experimental condition for evaluating the airflow system.

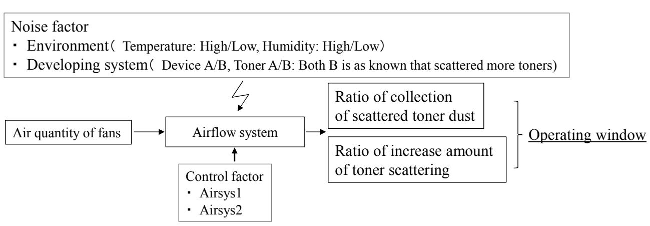

***Figure 6**. Parameter diagram for evaluating collection of toner dust*

The signal factor is air quantity of fans (four levels), and the response variables are the ratio of collecting the toner dust and the ratio of increase of scattered toner dust. The control factors are the two types of airflow system—Airsys1 and Airsys2, which are mentioned above. The noise conditions consisted of an environment with a developing system made up of developing device A and toner A, where the scattered toner is decreased (N1), and an environment with a developing system made up of developing device B and toner B, where the amount of scattered toner increases due to a lowered electric charge amount (N2). Thus, we used compounded noise factor in this experiment.

Results and Discussion

Functionality evaluation of airflow systems

The results of the experiment are shown in Figure 7.

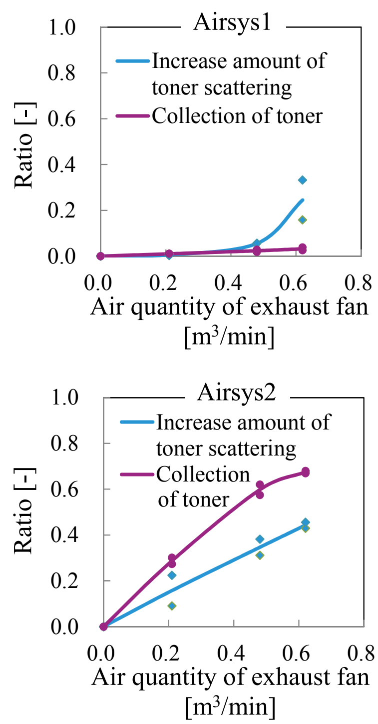

***Figure 7**. Functionality of collecting toner dust and suppressing toner scattering (Ratio of collecting toner dust and increased amount of scattered toner)*

This result shows that Airsys1 can indeed reduce the amount of scattered toner dust, but not collect toner dust as well. On the other hand, Airsys2 showed good performance in both collection and restraint. Also, upon calculating these S/N ratios, Airsys1 is more robust than Airsys2 by a difference of 17.4 db.

・Collection capability

In line with the concept for Airsys1, there are areas where the increase in scattering due to an increase in air quantity can be controlled. However, the toner dust collection rate remains low even with an increase in air quantity, and the rate of increase of scattering rises sharply with the threshold. Furthermore, in an air quantity range of more than 0.5 m^3/min, the rate of increase of scattering is higher than the collection rate. Meanwhile, Airsys2 is able to increase the collection rate about 17 times higher than Airsys1 when comparing the maximum air quantity.

・Dirt prevention

In order to clarify the extent by which the amount of adhesion of scattered toner, which is dirt, actually changes when air quantity is increased, the respective percentages that were obtained as described above were used to calculate the amount of adhesion of scattered toner per unit amount of scattered toner (Figure 8).

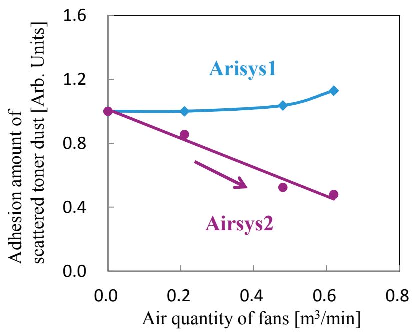

***Figure 8**. Adhesion amount per unit amount of scattered toner*

Figure 8 shows that in Airsys1, the adhesion amount increases steeply when the air quantity exceeds 0.5 m^3/min because the amount of scattered toner dust increases sharply. On the other hand, although the scattering in Airsys2 is increased, it is possible to reduce the amount of toner adhesion as a result of having higher collection performance. This result also indicates that Airsys2 is more suitable for collecting toner dust as compared to Airsys1.

The results mentioned above indicate that in cases where large air quantity in copying and printing machines is required, it is important to control the wind velocity at the vicinity of the developing nip by forming airflow in order to collect the scattered toner dust.

Considerations based on a mechanism of adhesion of scattered toner

We considered the reason why this difference occurs between Airsys1 and Airsys2, from the perspective of physical mechanisms. In order to grasp the relationship between the airflow and scattered toner, we investigated the distribution of adhered toner on the upper cover of the developing apparatus and that of wind velocity at the vicinity of that cover.

The distribution of wind velocity in Airsys1 transitions from an area with relatively fast wind velocity to an area with micro-wind velocity in an axial direction. Also, there are portions with adhered toner and portions without. On the other hand, the area of micro-wind velocity does not exist in the axial direction in Airsys2, and it was also found that the adhered amount of scattered toner is small. Figure 9 shows the measurement results of the relationship between wind velocity and amount of toner adhesion.

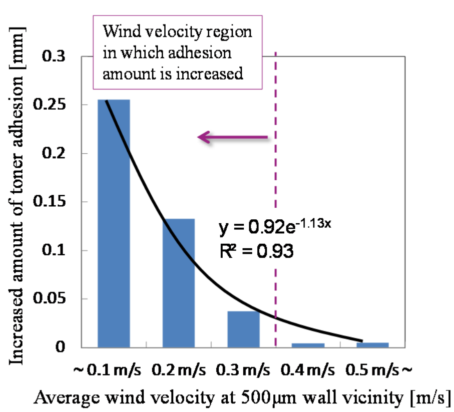

***Figure 9**. Relationship between wind velocity and toner adhesion*

This result indicates that sedimentation adhesion of scattered toner appears remarkably in micro-wind velocity area of less than 0.3 m/s due to an influence of gravity. Therefore, the adhesion amount increases steeply by reducing wind velocity.

This result also suggests that Airsys1 had areas of micro-velocity in the axial direction, and thus, sedimentation adhesion of scattered toner occurred. Therefore, even if air quantity was increased, collection was not possible only by increasing the amount of scattered toner; it is considered that the functionality of collection was not expressed. On the other hand, in Airsys2, distribution of wind velocity in the axial distribution did not have area of micro-wind velocity such as in Airsys1, and the collection rate increased as sedimentation adhesion could be prevented.

Moreover, since the relationship between the minimum wind velocity and the adhesion amount of scattered toner is as shown in Figure 9, it enables us to evaluate the functionality of airflow systems only from computational fluid dynamics, and without experiments using scattered toner.

Summary

The following conclusions were obtained from functionality evaluation of airflow systems with the objective of collecting scattered toner dust by using a dynamic operating window.

1. The usefulness of using the same evaluation to evaluate the trade-off phenomenon of collecting scattered toner dust and increasing the scatter amount was confirmed.
2. We discovered that an airflow system in which wind velocity is formed near the developing nip and controlled can prevent sedimentation adhesion of the scattered toner, and is effective in collecting toner dust.
3. It is possible to evaluate the functionality of airflow systems based on numerical analysis, without having to implement experiments using scattered toner.

References

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Author Biography

Kazuya Tamura obtained his masters in applied chemistry at the University of Tokyo in 2011. He joined Fuji Xerox Co., LTD. in 2011, and belongs to the Key Technology Laboratory (KTL). In the KTL, he is engaged in analysis of the noise, heat, dirt, and airflow systems in copying and printing machines.