ICSV14
Cairns • Australia
9-12 July, 2007

14th International Congress on Sound & Vibration

NOISE REDUCTION OF PERSONAL COLOR LASER PRINTER

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Abstract

Noise in a personal color laser printer is known to have an important influence on customer's acceptability. Noise incurred during printing may be perceived as being objectionable in quiet office environment even when the measured noise level is only moderate. To reduce printer noise, a good knowledge of the noise source mechanism is first required. In this paper major sources of printer noise are investigated by experimental approach. They are identified as drive noise, impact noise, and paper noise. Structural modifications are proposed to eliminate impact noise and paper noise by reducing the contact area. For the drive noise, it is proposed that the method of assembling motor-gear drive component into a main frame be changed. The proposed solutions are verified by mock-up test.

1. INTRODUCTION

Recently as a color laser printer comes into common use for office use, printer noise becomes more important factor for selecting a printer. Noise incurred during printing may be perceived as being objectionable in quiet environment because printers may be put on the computer table or nearby. Therefore, noise reduction of a color laser printer is required significantly.

A series of researches in the noise reduction of laser printer has been made previously. Preliminary study about structure-borne noise and paper noise was conducted [1] and also the statistical energy analysis was applied to reduce printer noise of laser printer in the wide frequency range [2]. In this paper, experimental approach is introduced to reduce printer noise of personal color laser printers. Since it is important to identify major sources of noise common in color laser printers, the noise source mechanism should be investigated carefully. The noise source mechanism of a color laser printer can be classified into three types, i.e. drive noise, paper noise and impact noise. For paper noise and impact noise, their noise generation mechanisms are examined experimentally and structural modifications are applied to eliminate each noise source itself. For drive noise, the contribution of main drive paths to overall noise of color laser printer is estimated experimentally. Also, the reduction method of drive noise is suggested based on the result of analyzing the effect of assembling method on overall drive noise. Finally the solutions proposed in this study are applied to a mock-up and are validated by the comparison test of the original design and the modified one.

2. NOISE SOURCES OF COLOR LASER PRINTER

To find out the noise source mechanism of a color laser printer (see figure 1), a series of noise tests is conducted in an anechoic chamber. Figure 2 shows an example of time signal of printer noise generated when a sheet of a color image is printed. As shown in figure 2, each peak represents impact noise generated from drive part at the phase of shifting each color development roller in the order of yellow, magenta, cyan and black. The base noise excluding impact noise components from time signal is caused by paper noise and drive noise of motor and gear train.

Figure 1. A color laser printer used in this study.

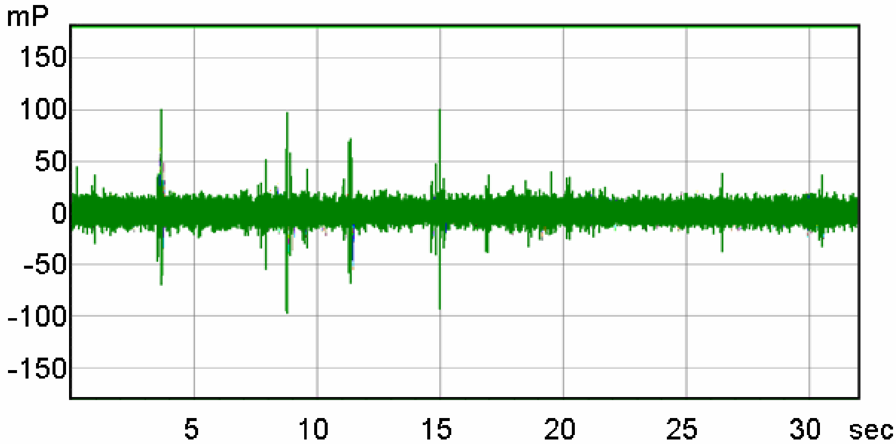


Figure 2. An example of time signal of printer noise of color laser printer when a sheet of a color image is printed.

Overall noise level is measured to figure out influence of each operation conditions such as main motor drive only, laser scan unit (LSU) drive only, and one-sheet or consecutive print of a monochromic or color image. The results are summarized in table 1. It can be seen that overall noise level of consecutive print of a monochrome is largest.

From figure 2 and table 1, the noise source mechanism of printer noise of color laser printer can be classified into three types, i.e. paper noise, impact noise and drive noise. First, paper noise indicates friction noise between papers or between a paper and guides when a paper is being fed. Second, impact noise is generated from gear impact when each color development roller is shifted and/or each clutch is engaged. Third, drive noise is caused by motor and/or gear train operated to drive components such as pick-up roller, registration roller, organic photo conductor (OPC) drum, fuser roller, toner roller, image transfer unit (ITU), etc. Drive noise is similar to warm-up noise except impact noise by color development clutch. Next, noise reduction methods are studied with respect to noise source mechanisms respectively.

Table 1. Noise level with respect to operation conditions.

Operation condition		Noise level [dB]
Warm-up		43.9
Main motor only operated		41.1
LSU only operated		32.9
All operated without papers		41.7
Consecutive print	Monochrome	48.0
	Color image	46.0

3. PAPER NOISE

As mentioned earlier, paper noise is generated by friction between papers or between a paper and guides when a paper is picked up from paper cassette and then is moving in paper path. The key point to improve paper noise is to reduce contact area that determines friction noise.

In this study, in order to reduce contact area (as shown in figure 3) it is proposed that guide structures between a pick-up roller and a registration roller are integrated into a continuous body with minimal area. Fuser guide is modified to reduce contact to front edge of a paper as well.

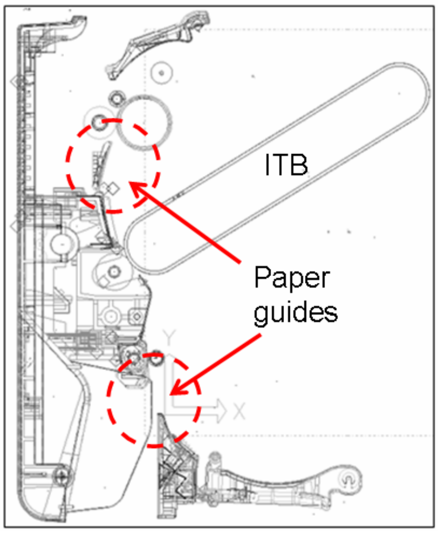


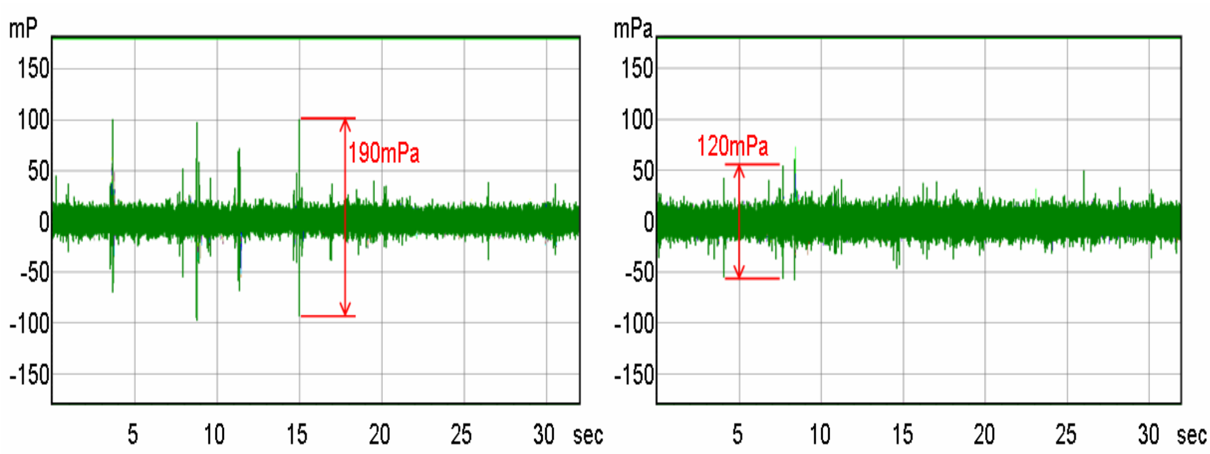
Figure 3. Contact area to improve paper noise.

The proposed modifications are applied to make a mock-up. Noise level test is conducted to compare the modified model with the original model and results in reduction of overall noise level of about 3 dB on consecutive print of monochromic image.

4. IMPACT NOISE

A color laser printer used in this study has a mechanism with a cam shaft which causes four cams to drive corresponding color development roller using only one drive motor. The moment a master gear on the part of cam shaft is engaged into or disengaged from corresponding slave gear on the part of development roller, impact noise is generated. Therefore, printing a sheet of color image, four times of impact noise is produced according to yellow, magenta, cyan and black prints, as shown in left figure of figure 4. Impact noise is a small part of overall noise level, but has to be improved because it grates on users' nerves.

In this study, it is suggested that the number of teeth of master and slave gears be decreased in order to reduce impulse generated between master gear and slave gear by engaging drive cam of four color development rollers. This modification is evaluated by mock-up test as shown in figure 4. Comparing peaks of noise signal of the original with modified models, it can be seen that noise reduction of about 60% is made.



(a) Original model (b) Modified model

Figure 4. Impact Devi clutch noise improvement by reducing number of clutch tooth.

5. DRIVE NOISE

The main causes of drive noise are motor and gear train in charge of printer operation. Figure 5 shows a result of the frequency analysis of drive noise signals. As shown in figure 5, tooth frequency of main motor, mesh frequencies and their harmonics, and side band frequencies can be found out.

In this study, gear shape tolerance, distance variation of gear shafts, assembly tolerance of gearbox and so forth are not considered because these belong to issues of gearbox itself. Instead, authors have focused on the tolerance of assembling gearbox into printer frame.

The cause of tolerance of assembling gearbox into a frame is deformation of a bracket of gearbox by bolt torque, mold or injection variations, etc. First of all, bolt torque is investigated to find out the effect of torque on overall noise level. Figure 6 shows a layout of bolt positions. For bolt torque of 1 and 2 kgf·cm, noise measurements are conducted and the result is shown in table 2. From the results of table 2, it can be concluded that the bolt torque does not affect overall noise level significantly.

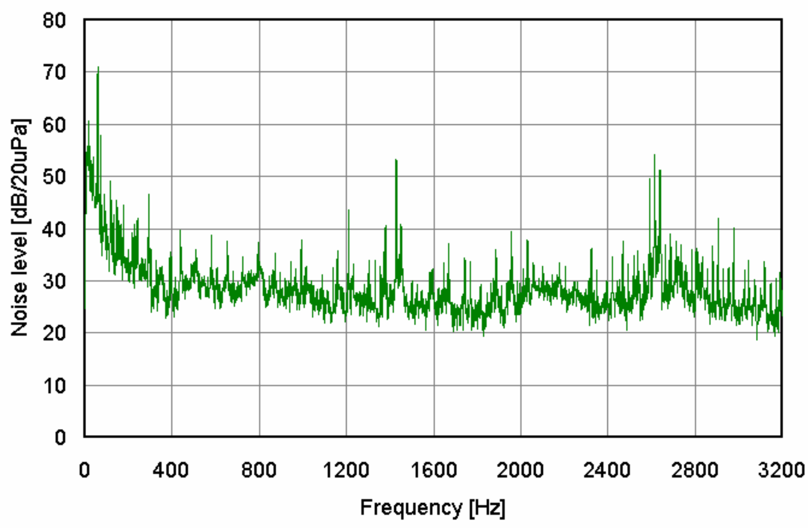


Figure 5. FFT result of printer noise signal

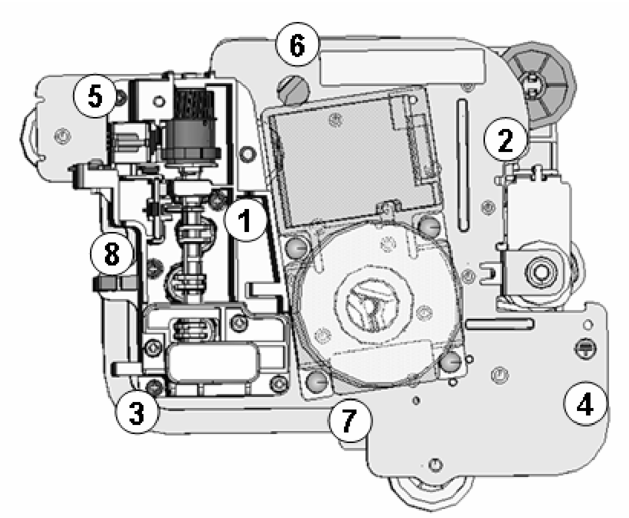


Figure 6. Bolt position on the bracket of gearbox assembled into a frame.

Table 2. Noise level with respect to changing bolt torque.

Bolt torque	Noise level [dB]
1kgf-cm	42.7
2kgf-cm	42.1

Next, the effect of assembly tolerance between gearbox and a frame on overall noise level is analyzed by changing bolt positions. The analysis result is shown in table 3. Just using one bolt (no. 1 in figure 6) the noise level is minimal. It is because the assembly tolerance is eliminated due to no deformation of a bracket and a frame not using bolts except one. To assemble gearbox into a frame without any deformation and be parallel with each other, three bolts are recommended to be good to fasten gearbox on a frame. In this case, bolts of no. 3, 4, and 6 show good results.

In conclusion, the method of using small number of bolts to reduce drive noise is suggested to show overall noise reduction of about 1 dB. The proposed method to reduce drive noise is verified but its effect is less than those of paper noise and impact noise.

Table 3. Noise level with respect to bolt positions.

Bolt position	Noise level [dB]
Original (8 bolts)	42.7
Bolt no.1 only	41.0
Bolt no. 3, 4 and 6	41.7
Bolt no. 2, 5 and 7	42.7
Bolt no. 1, 3 and 7	41.9

6. CONCLUSIONS

In this paper, experimental approaches are introduced to reduce noise of a personal color laser printer. From the analysis results of noise measurements, noise of a color laser printer can be classified into paper noise, impact noise and drive noise. The noise source mechanism is investigated respectively.

First, in order to reduce paper noise some modifications of guide structure are introduced of minimizing contact area between papers or between a paper and guides. It is equivalent to reducing friction resistance. Second, the number of teeth of master and slave gears used to transfer drive force to color development roller is reduced in order to eliminate impact noise generated from coupling master and slave gears. Third, to reduce drive noise the number of bolts used to assemble a gearbox into a printer frame should be decreased to minimize the deformation of a bracket of the gearbox and the assembly tolerance between the gearbox and the frame.

The proposed solutions are applied to a mock-up and verified by noise experiment. Finally, it can be seen that the overall noise reduction of about 3 dB of consecutive monochromic print is obtained from the modified method.

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