Low Noise SIDM Printers

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An SIDM (Serial Impact Dot Matrix) printer is a type of printer that forms characters onto printing paper with dots, which are generated by impact onto the paper via an ink ribbon using wires with a 0.2 mm to 0.3 mm diameter, located inside the printhead. Although inkjet printers and page printers dominate the current printer market the demand is stable for SIDM printers due to the features that include the ability to print duplicating papers for industries that use forms and slips, such as the distribution and logistics industries.

The core technologies of SIDM printers are primarily the same as those established a dozen or so years ago when this type of printer was still the mainstream printer in the market. Nowadays, however, added value technologies in pursuit of customer satisfaction have been in demand, requiring the development of new technologies. A noise reduction technology can be cited as one such technology.

Noise not only affects our auditory sensation, but it is also discomforting, it offends people's feelings and otherwise brings on various negative aspects to human beings. It is also for this reason that a noise reduction technology for SIDM printers is being considered important.

Noise emitted by SIDM printers can be categorized mainly into printing noise and frame vibration noise, as shown in **Fig. 1**. Noise reduction methodologies for reducing the noise generated by printing sounds and frame vibration sounds caused by the spacing operation are introduced in this paper.

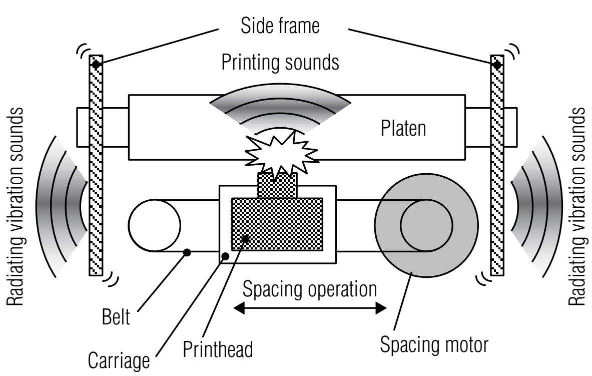

Fig. 1　Major noise sources of SIDM printers

Reducing printing sounds

Because SIDM printers use wires to print on printing paper, a particularly large noise is generated during printing. A printhead is configured using multiple wires, the number of which depends on the specification (resolution) of the printed characters. In regions where alphanumeric characters are used printheads are generally comprised of nine wires arranged perpendicular in the direction of the spacing. For this reason the printing noise does become more significant when characters with vertical lines are printed, such as the characters “I” or “H”, due to simultaneously printing.

(1) Noise effectively reduced from dispersive impact

A test pattern was created to verify the relationship between the simultaneous impact frequency and noise. The impact timing for the aforementioned test pattern is shown in **Fig. 2**. The dispersive impact pattern involves the use of eight wires with the wires impacting one at a time and an equal interval between wires. The process is repeated for this test pattern. The simultaneous impact pattern involves eight wires impacting at the same time, with a break taken for every seventh set of impacts. The process is repeated for this test pattern also. The dot density per unit of time for the test pattern is identical for both of these patterns.

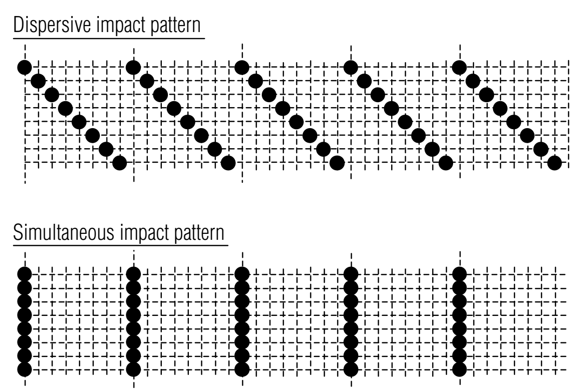

Fig. 2　Impacting timing of test patterns

The graph in **Fig. 3** represents an acoustic pressure time waveform for each test pattern. The peak value for the amplitude of an acoustic pressure time waveform for the simultaneous impact pattern is approximately double that of the dispersive impact pattern. The attenuation also continues half of the time during which printing was suspended.

Fig. 4 represents an analysis of 1/3-octave band frequency derived from measuring noise levels at a point-blank distance. Dispersive impact patterns show a peak value attenuation for the 2,500 Hz frequency band, along with a reduction in noise levels for the respective frequencies. Furthermore, it was verified that for AP (All Path), the dispersive impact pattern yielded a noise reduction effect with 59.9 dB and 1.8 dB in comparison with 61.7 dB for simultaneous impact patterns. Although the impact patterns used for both patterns were extreme, a numerical verification was obtained indicating that noise reduction effects can be obtained through the dispersion of the impacting timing of wires.

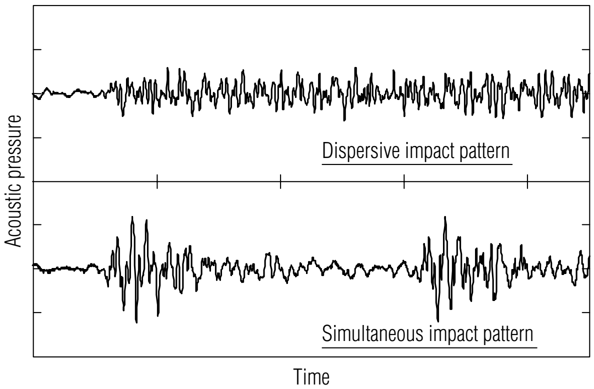

Fig. 3 Acoustic pressure wave form

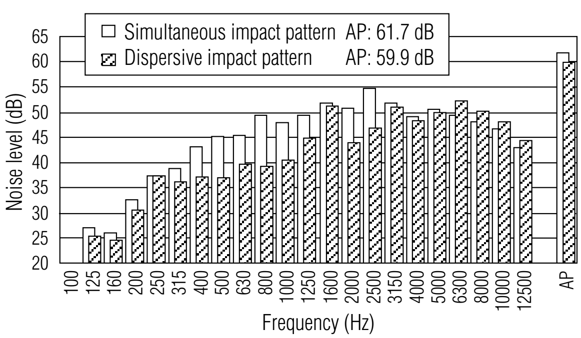

Fig. 4 Noise levels of respective patterns

(2) Wire arrangement simulation

It has already been mentioned that reduced noise effects can be obtained by reducing the frequency of the simultaneous impact. To clarify the relationship between the wire arrangements and impacting frequency a simulation was conducted.

Fig. 5 depicts the wire arrangement with which verification was conducted and a slanted arrangement with the angle of inclination is defined as $\theta = \tan^{-1} (a \cdot \Delta X/\Delta Y)$. The "ΔX" and "ΔY" represent the horizontal dot pitch and vertical dot pitch of matrix. The character "A", for example, is composed of a dot configuration shown in the diagram. The "a" represents a fraction of ΔX, which is the horizontal dot pitch and this in turn determines "θ". When a = 0, then θ = 0 representing a conventional linear wire arrangement. When a = 1, $\theta = \tan^{-1} (a \cdot \Delta X/\Delta Y)$ representing a slanted wire arrangement that passes through the intersecting point of the vertical and horizontal dot pitch.

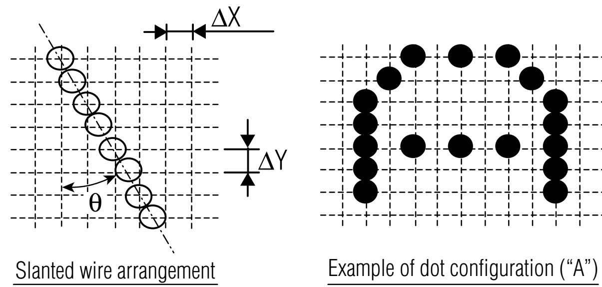

Fig. 5 Simulated wire arrangement diagram

Table 1 Frequency of simultaneous impact and equivalent noise levels for each respective wire arrangement

		Fraction a						
		0	1/6	1/3	1/2	2/3	5/6	1
Number of wires impacting simultaneously	One	42.7%	97.9%	86.9%	82.1%	88.1%	99.2%	64.9%
	Two	31.5%	2.1%	12.3%	17.4%	10.9%	0.8%	28.2%
	Three	10.2%	-	0.8%	0.5%	1.0%	-	4.9%
	Four	4.7%	-	-	-	-	-	1.2%
	Five	3.6%	-	-	-	-	-	0.4%
	Six	1.9%	-	-	-	-	-	0.1%
	Seven	5.4%	-	-	-	-	-	0.3%
Equivalent noise level		75.6dB	67.7dB	70.7dB	71.7dB	70.7dB	67.7dB	75.6dB

Table 1 shows a simulation for the frequency of simultaneous impact and equivalent noise levels when the respective wire arrangements use "a" as a variable to print the main characters (alphabetical characters, numbers and various symbols) with an SIDM printer. The simultaneous impact frequency referred to here represents the ratio of simultaneous impact by one to seven wires against all impact counts. Equivalent noise levels were simulated using an acoustic pressure waveform. For the purpose of simulation, measurements of an acoustic pressure waveform for single dot printing, P1 (t), were taken. The results were used together with the weight, Wi, for the respective impact timing obtained from the simultaneous impact frequency and divisional patterns, along with the impact timing Δti, to formulate an acoustic pressure waveform using the formula, $Pa(t) = \Sigma[W_i \cdot P1(t + \Delta t_i)]$. In this manner an acoustic waveform was obtained and used to perform simulation of the equivalent noise levels. The divisional patterns come in seven types based on a = n/6 (where n is an integer of 0 to 6).

Table 1 indicates that although the frequency of a single wire impact in a conventional wire arrangement with a = 0 was 42.7%, improvements were made with each fraction, a. When a = 1 simultaneous impacts involving many wires occur as the wire arrangement coincides with the dot pitch. The frequency of a single wire impact was 80% or more when a = n/6 (where n is an integer of 1 to 5) and impact involving four or more wires did not occur.

Looking at the equivalent noise level, on the other hand, we found that even though a conventional wire arrangement with a = 0 generated 75.6 dB, the most minute fraction, a = 1/6, brought about 67.7 dB resulting in an effect of 7.9 dB. Even with the least effective fraction, a = 1/2, provided an effect of 3.9 dB. Although this simulation does not take into account any resonance sound that can be generated when the constant value of printing noise and the impact timing happen to coincide, we did obtain an effective noise reduction, which increased as the fractions that resulted in more minute impact timing were selected.

A wire arrangement with a = 1/2 was used in the product level verification on the effects of reducing noise described later on in this paper, in order to secure adequate impact timing to prevent magnetic interference that can destabilize wire operations.

Frame vibration noise reduced

A stepping motor was adopted as the motor for the sweeping operation of the printhead in the horizontal direction. The point of concern with control of the stepping motor was the generation of vibrations when it rotated at low speeds and the lack of torque when it rotated at high speeds[1]. The vibration generated with low-speed rotations in particular was a significant element of frame vibration.

A two-phase excitation method that is operated with magnetic excitation and basic step angles is a common method, however, the vibration of the rotor with this method is significant as the rotor is repeatedly turned and stopped. Changing the excitation method to the 2W1-2 phase excitation method (microstep method) can be cited as a strategy to counter this issue. It is possible to perform extremely rapid changes in speed and reduce the rotor vibration with the microstep method by dividing the basic step rotation angle of the motor for excitation.

A lack of torque, however, does occur at high rotating speeds when the microstep method is used. A primary delay occurs in the rise of the electric current due to characteristics of the voltage when applied to the coils of the motor. Since ordinary levels of electric current do not flow immediately the required amount of torque cannot be generated.

Using a two-phase excitation method can be cited as a strategy to counter the issue of shortage in torque at high rotating speeds. By not dividing basic step angles to secure the time for the electric current to flow in ordinary conditions during the excitation period of each phase, it would be possible to generate an adequate amount of torque.

If the microstep method is used for low rotating speeds and the two-phase excitation method is used for high rotating speeds, it would be possible to control the motor using excitation methods suitable for a particular speed range for the reasons described thus far, thereby providing a very effective means for reducing noise.

The function necessary for the control circuit is a means of switching the excitation method from a two-phase excitation method to a microstep method at will even when the motor is turning, as shown in **Fig. 6**. Such a function can be realized by compensating for the excitation phases and excitation timing with hardware to ensure that the rotor turns smoothly during the switching between the excitation methods.

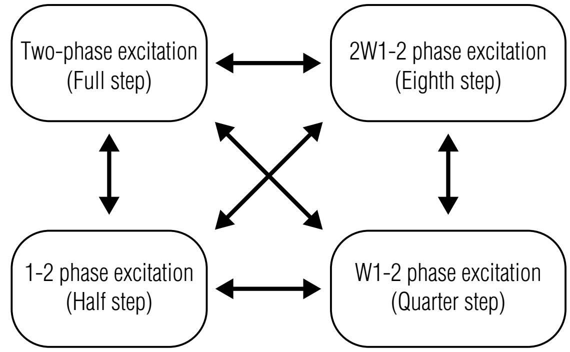

Fig. 6 Switching of excitation methods while motor is turning

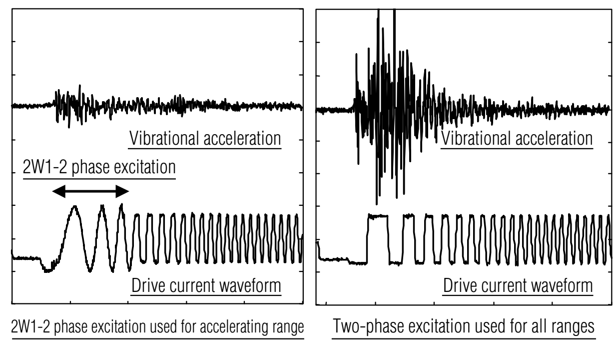

Fig. 7 Frame vibration acceleration temporal waveform during spacing operations

The graph in **Fig. 7** shows this function used to drive a stepping motor and a conventional method used for driving a stepping motor. The graph on the left shows the vibrational acceleration waveform for the side frame when the 2W1-2 phase excitation method was used at a low rotating speed range (accelerating range) and the two-phase excitation method used at a high rotating speed range. The graph on the right shows the vibrational acceleration waveform for the side frame when a two-phase excitation method was used for all ranges.

In comparing the two graphs the adoption of the microstep method for the graph on the left shows reduced frame vibration. Furthermore, switching to the two-phase excitation method was a strategy to counter a shortage in torque while making it possible to drive a stepping motor with a reduced vibration.

Product level verification of reduced noise

So far printing control for SIDM printers and methodologies for reducing noise through motor control have been described. The results from product level verification of these noise reduction technologies will now be introduced. A product with a frame that is not rigid and thus more likely to be impacted by vibration during a spacing operation was used for the verification.

First of all, the noise reduction effect due to the microstep control during a spacing operation will be described. The graph in **Fig. 8** represents noise levels when only the spacing operation was performed. The noise level was reduced over the entire frequency band range using the microstep control. With AP the microstep control brought about a reduction in noise of 4.1 dB with 43.0 dB in comparison with 47.1 dB with two-phase excitation control.

The noise level obtained when the slanted wire arrangement control was adopted as a printing control on top of the microstep control is shown next in **Fig. 9**. The noise levels for the printing noise component is the portion of noise that increased within or above the1,250 Hz band in comparison with the values in **Fig. 8**. Since the printing noise is significantly larger than the spacing operation noise, the effects of the microstep control in this frequency range were diminished. In the 3,150 Hz band, however, the effect of the slanted wire arrangement control reduced the peak noise value by about 6 dB.

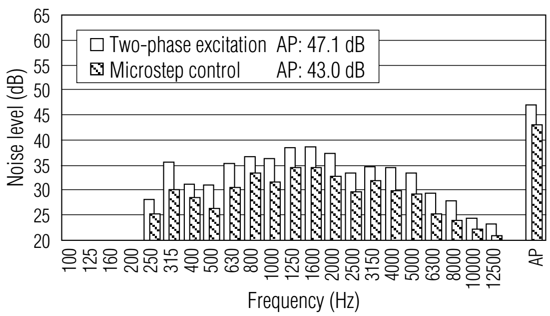

Fig. 8 Noise level when motor is driven only for spacing operation

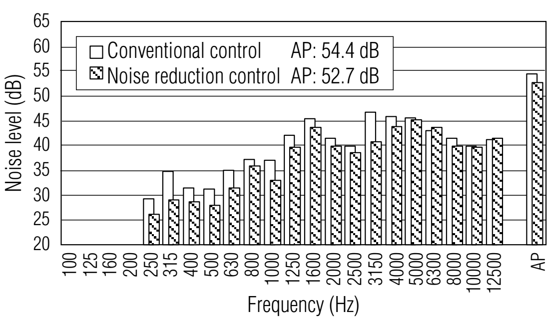

Fig. 9 Noise level for driving in all ranges

In general when multiple sources of noise exist, it is necessary to implement strategies for the larger sources of noise first[2]. Peak values were decreased for printing noise and noise was reduced over the entire frequency range for the spacing operation noise. As for AP, the conventional control method generates 54.4 dB of noise, while we obtained 52.7 dB, which is a noise reduction of 1.7 dB.

The timing of the vibrational noise generated differs between printing noise and spacing operation accelerating and decelerating ranges, however, it was possible to actually audibly experience individual effects. The printing operation became a light tone with a high note, whereas the noise of the spacing operation, the frame vibration noise that was generated in a "tittup" manner, became unnoticeable.

Conclusion

This paper described noise reduction methodologies using mechatronic controls for SIDM printers. These methods can be implemented without the addition of any parts or materials for noise reduction strategies to reduce noise. Along with reducing noise, they can contribute greatly to reducing costs as well.

In the future we intend to develop products that are friendly to humans by targeting the "Deepening of 4L Technologies", which offer not only noise reduction technologies (Low Acoustic Noise), cost reduction technologies (Low Costs), but also power consumption reduction technologies (Low Power Consumption) and running cost reduction technologies (Low Running Costs).

References

1) Kinji Tanikoshi, "Practical Technologies for Stepping Motors", First Edition, Dempa Shimbunsha, pp. 68 to 83, 2006.
2) Aritomo Nakano, "Noise Reduction Technologies", First Edition, Gijutsu Shoin, pp. 21 to 23, 1993

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TIPS

Noise standard for printers

The International Standardization Organization, ISO, has standardized noise values for information technology equipment, including SIDM printers. The Japan Industrial Standard, JIS, has also established standardizations that comply with the aforementioned standardization. Main standardizations include JIS X 7778 (ISO 9296), "Acoustics -- Declared noise emission values of computer and business equipment", as well as JIS X 7779 (ISO 7779, ISO 9295) "Measurement of airborne noise emitted by computers and business equipment" can be cited as some principal standards of such types. Data formats, verification methods and measuring methods for noise generated by information technology equipment, such as printers, are stipulated by such standards. Product level measurements of noise referred to in this paper have been taken using test patterns stipulated by JIS X 7779.