Study of Improved Heating Head High Speed Heating and Efficient Usage

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Abstract

HIT Devices Ltd., developed the HDR-0670 heating head. The structural difference between this heating head and the existing products is basically the contact surface with the media is not the heat-generating side of the substrate. The media contacting surface is made of ceramic which has excellent anti-abrasion capability and it can be treated according to the application purposes for various media. Also, it utilizes the thermal energy efficiently by employing the structure which transfers the generated heat to the media effectively by observing the surface temperature drop at the time of media contact. It is possible to heat the necessary part of the media with the proper temperature for the determined amount of time easily by the combination between the heating head and temperature control circuit which monitors and measures the amount of heat transferred on real-time. The heat transfer between the heating head and media when the media moves at high rate was investigated. This report is the result of study of diverse and efficient usage methods including the improvement and kaizen of explicit or hidden problems by visualizing (mieruka) and analyzing the various thermal characteristics.

Heating Head Background

The history of heating head starts with the thermal printhead which was invented by Texas Instruments Inc. in 1965. Desk-top calculator with thermal printer as the output device which uses small dot matrix serial printhead to print alpha-numeric characters on the thermal sensitive paper became popular in the beginning of 70s; High speed line-type thermal printhead with the driver IC mounted on the substrate came out by the end of the 70s. This enabled the markets in the fax machine and bar code for retail to expand greatly in the 80s.

Rewritable media which the printed information can be erased and reprinted became available for loyalty card and transportation pass applications. Printing on the rewritable media is accomplished by the thermal printhead, but erasing is done more efficiently with heating head which the temperature can be controlled over wide area. The heating head was developed for rewritable media in the beginning, but its usages are widening for such as ID card lamination and thermal retransfer process.

Figure 1 shows the basic structural difference between the thermal printhead and heating head. Thermal printhead has the heating element dots in line and the dots can be turned on independently. However, the width of line of dots are narrow as it corresponds the print resolution. The heating head, on the other hand, the heating element is continuous strip-shape single piece and there is a freedom in width design. If wide contact width with the media is required, heating element width can be designed accordingly.

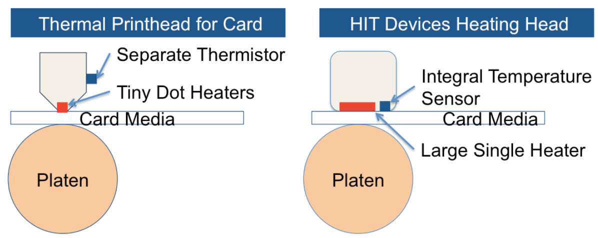

Figure 1
Structural comparison between thermal printhead and HIT Devices conventional heating head

Basic structure of the new heating head

The new heating head has the heating element on the back side of heating surface of the ceramic substrate.

Figure 2 shows the comparison of the structural difference. Since the surface which touches the heated media is made of ceramic for the new heating head, it is quite anti-abrasive and anti-chemical to withstand harsh environment. The temperature sensor is formed near the heating element on the same layer and it is possible to detect the heating element layer temperature changes accurately. The heating element and temperature sensor layer are formed on the ceramic substrate of the head mounting bar side (vs. media heating surface side). There is an adhesive layer between the ceramic substrate and the ceramic board which aids in thermal insulation to make the heat to be conducted easier to the heating surface side.

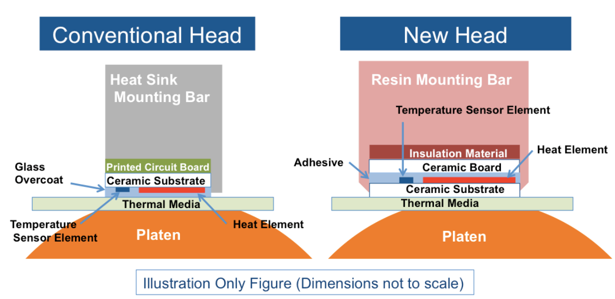

Figure 2
Structural comparison between the HIT Devices conventional heating head and new head

Relationship between the media speed and heat flow amount

The new heating head and our conventional head (model HDE-560) are both for plastic card application. However, the new head was designed to accommodate the larger thermal load and greater heat flow amount which are often required for such applications as plastic card film lamination. The increase of thermal capacity is achieved by heating the ceramic substrate from the back side and making the whole substrate the heating surface. Additionally, the ceramic substrate is widened to increase the card contact area. In case a higher head force is required, an optional overcoat material is available to reduce the sliding friction.

We see the theoretical heating time for the given card material. When the card is made of PVC with ISO Standard card size of 85.60 x 53.98 x 0.76 (mm), the thermal capacity is 4.8 J/ºC for the volume. If the temperature of the whole card has to be elevated by 125 ºC from 25 ºC to 150 ºC which is the erasing temperature for the rewritable media, 600 J of energy will be required. The amount of time is 7 seconds if 85 W of power is applied assuming that 100% energy conversion is achieved. This is equivalent of heating the card running vertically at 12 mm/sec.

In practice, however, there is no need to heat the whole card but the erasing is done if the temperature of the coloring layer is raised to the required level. For that reason, erasing speed is generally from 30 mm/sec to 60 mm/sec in industry. For plastic card lamination, speed is slower in general from 8 mm/sec to 15 mm/sec as the card surface needs to be heated through the lamination film.

Heat flow amount from heating head to media is determined mainly with the media which touches the head surface, its moving speed and head force.

The control circuit used for the experiment has the fixed cycle pulse of 100 μs with pulse width modulation (PWM) method. This circuit is connected to the PC with dedicated software and temperature can be preset as shown on Figure 3. Additionally, it is possible to measure the heat flow amount by reading the time transition data of PWM control condition on PC.

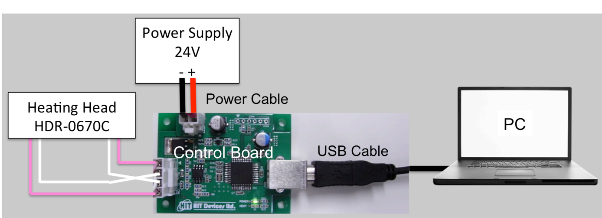

Figure 3

Control circuit used for heat flow amount measurement

The change of heat flow amount when the aforementioned plastic card speed was varied was measured. Our conventional head HDE-560 and new head HDR-0670 were compared under the condition of sensor temperature maintained at 150 ºC. The head force for both was kept at 19.6N (2 kgf). The heat flow amount to the media was defined and calculated as follow.

Heat flow amount = Power with media in contact - Power with no media contact

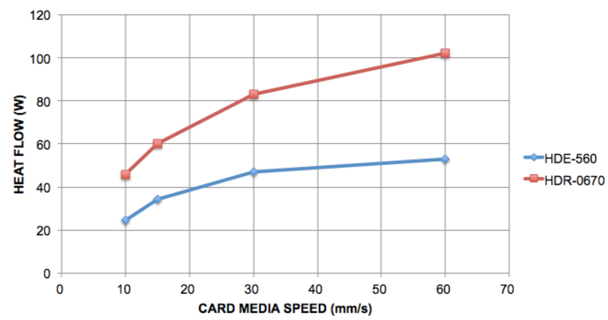

Figure 4

Relation between the heat flow amount to the media and media moving speed

The heat flow amount increases as the media speed increases. Also, the new heating head heat flow amount is greater compared with the conventional head. This is due to the design of new head having the whole ceramic substrate heating the media. This resulted in the greater amount of heat flowed to the media.

When the heat capacity is larger, the amount of time to reach the preselected temperature becomes longer at the same power. Figure 5 shows the relationship between the time and power for the new and conventional heads from 25 ºC to 150 ºC without media touching the heating surface.

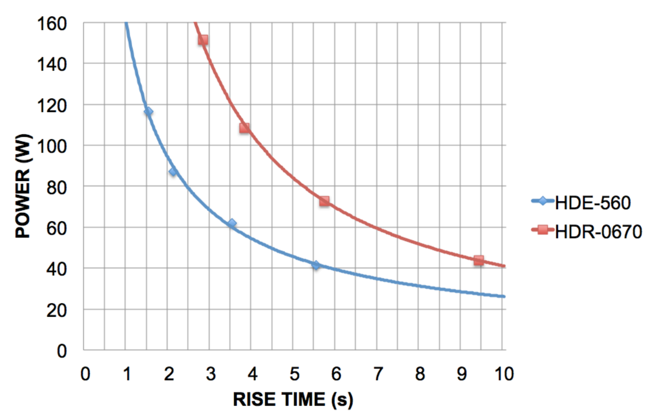

Figure 5

Relationship between power and time

When both heads were energized at 100 W, the conventional head HDE-560 reached 150 ºC at half time of the new head.

Figure 6 explains that the new head is more energy efficient as it can maintain 150 ºC with 12 W on standby state while the media is not in contact with the head, while the conventional head requires 20 W under the same conditions.

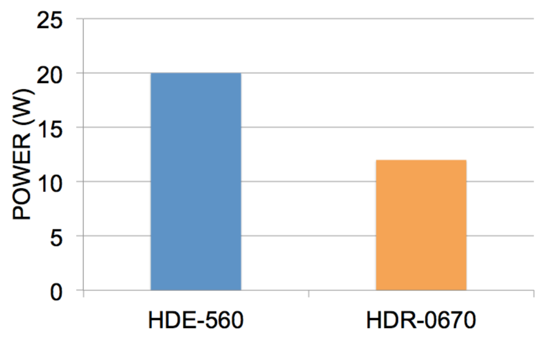

Figure 6

Power comparison to maintain 150ºC while the media is not contact

This is because the new head mounting bar material is made of resin-base which has the higher thermal insulation capability while the conventional head is using the aluminum material as shown in Figure 2.

Our discussion has been based on the temperature of the heating element. If we look from the media view point which is being heated, there is a temperature difference between the heating surface and heating element due to the temperature gradient.

Relationship between the media speed and temperature gradient (temperature difference)

Larger heat flow amount is seen when the media speed is increased because the thermal dissipation become greater. For the new head, the heat generated by the heating element goes through the ceramic substrate to reach the media. Since there is a thermal resistance on the ceramic, there is a temperature difference in proportion to the thermal resistance when the heat flows through. When there is a difference in temperature within the substance, heat will move from the higher temperature to the lower temperature.

The relationship among the heat flow amount Q, temperature difference T and the thermal resistance R between the heating element and heating surface is shown below:

Heat flow amount Q = Temperature difference T / Thermal resistance R

The thermal resistance from the heating element to the heating surface for the new head HDR-0670 is 0.10 ºC/W and the temperature difference of 10 ºC will be needed if 100 W of heat flow amount has to be moved. In practice, the temperature difference is from the heating element to the layer to be heated on the media. In this instance, it is necessary to take the contact thermal resistance into consideration. The contact thermal resistance depends upon the surface physical conditions and contact force between the heating surface and the media. If there are air gaps due to the material surface unevenness, the thermal conduction efficiency degrades and thermal resistance goes up. Figure 7 is the graphic representation of the contact thermal resistance and temperature gradient.

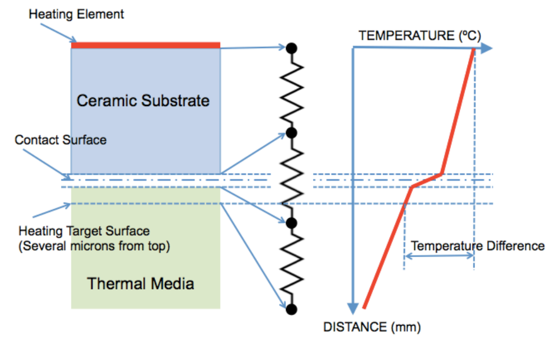

Figure 7

Contact thermal resistance and temperature gradient

Since the layer to be heated is several microns under the media surface as shown on the figure, this must be added to the contact thermal resistance. Also, the area which the heat flow through is affected by the nip (footprint of platen roller pressed against the media) width. The actual thermal resistance is considered to be greater than 0.10 ºC/W.

In general, it is not easy to measure the media surface temperature while the heating head is in contact with the media. We used the special thermal sensitive paper which is called Temperature Indication Paper HTP-1017. This paper has near linear optical density characteristics between 100 ºC and 200 ºC temperature range as shown Figure 8.

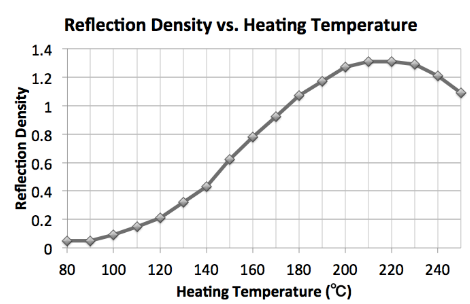

Figure 8

Temperature Indication Paper characteristics

The media surface (coloring layer) temperature was measured with the paper at various media speed while the sensor temperature was kept constant at 150 ºC as shown on Figure 9. The heat flow amount was the same as defined previously, but the result differs from Figure 4 since the media is thermal sensitive paper rather than a plastic card.

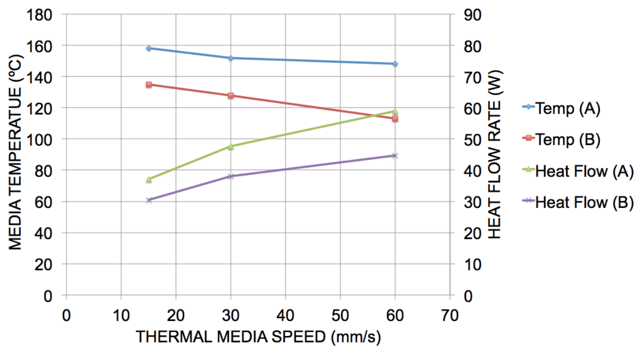

Figure 9

Relationship between the media speed and temperature difference

The new head is designed to withstand the shearing force of bidirectional media movement. The positional relationship between the heating element & temperature sensor and the media temperature distribution are shown graphically on Figure 10.

For the media direction (A), the temperature sensor location is before the heating element. For media direction (B), the sensor is after the heating element. Although the sensor temperature was kept at 150 ºC and the media surface temperature is within the nip width, the results are different as the thermal diffusion occurs based on the distance as the media passes through the head. The thermal diffusion image while the media is moving is illustrated on Figure 10,

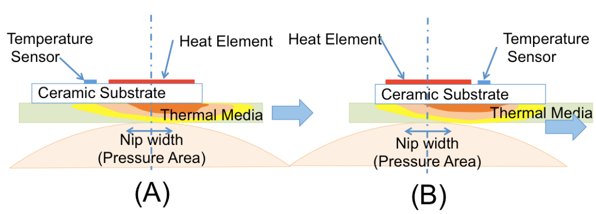

Figure 10

Relationship between the media direction and location of thermal sensor

The direction (B) is more suitable for taking the final temperature reading of the media as the media temperature goes up as it goes through the nip width. The direction (A), however, the sensor reading represents the heating element temperature better as well as the effect of the temperature rise of the media will be included. This results in the increase of the energy to the heating element and temperature rise as the media leaves the nip area. Although the temperature gradient exists, the compensation action for the temperature increase is in effect. The direction (A) has the advantage of being able to heat the media surface with the selected temperature.

When the media speed increases, the temperature of the media coloring layer decreases since the temperature gradient increases as the heat flow amount becomes greater. Therefore, it is necessary to select the temperature of the sensor setting to take the temperature difference into account. The important point for more power efficiency is to minimize the temperature gradient from the heating element to the media heating surface.

Issue for Speed Improvement

The locational relationship between the heating element / sensor and the platen roller becomes more critical for higher speed. From the thermal conduction efficiency point of view, it is believed to be better to line up the center of heating element and platen roller center.

The heat flow amount and media surface temperature change were measured while the heating element to the roller distance was varied using the new head HDR-0670. In order to see the characteristic difference, the nip width was maintained at 2 mm. When the heating head is moved same direction as the media, it is defined as "plus" and opposite direction as "minus". So, the direction (A) on Figure 10, moving the head "plus" side means the sensor moves toward the platen center. For the direction (B), the situation is reversed and moving the head "minus" side makes the sensor comes closer to the center of platen.

Figure 11 shows summary of the experiment for the temperature and power in relation to the amount of head movement (offset) when the media is moving at 60 mm/sec. The Y-axis scale is for both the temperature (ºC) and the power (W).

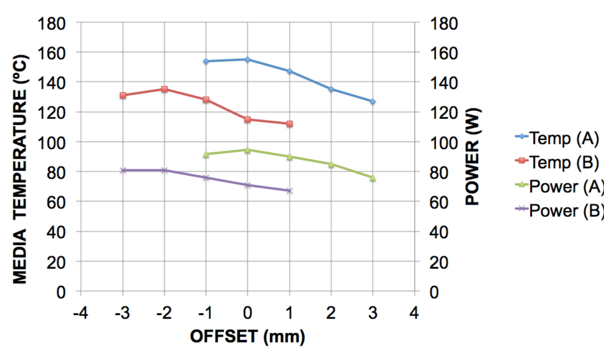

Figure 11

Thermal Characteristics of New Head Placement against the Platen Roller

The result of the experiment shows that the direction (A) without offset and (B) with offset of minus 2 mm give the best result. The experiment shows the importance of heating head set up in relation to the platen roller especially when the media is moving.

In order to realize the higher speed heating of media from the heating head point of view, there are several points to be considered as follows:

1. Increase the head heating surface area and make the contact time with the media longer.
2. Increase the smoothness and reduce the coefficient of friction of the head heating surface.
3. Design the heating head with higher driving voltage and current.
4. Select the material which reduces the temperature difference between the heating element and heating surface.

In practice, for example, the substrate material can be made with higher thermal conductivity such as aluminum nitride (AlN) rather than alumina (aluminium oxide) which has been used in the current heating heads.

Possibilities for the New Heating Head

The subjective comparison between our conventional heating head and new heating head is as follows:

	Conventional Heating Head	New Heating Head
Manufacturability	Good	Better
Heating surface anti-abrasion	Good	Exellent
Heating surface smoothness (surface overcoat)	Good	Better
Thermal capacity	Fair	Better
Temperature rise time	Excellent	Good
Thermal gradient	Excellent	Fair
Bidirectional	No	Yes

Both of our heating heads, conventional and new type, have the thermal sensor and heating element are located in the near vicinity on the same side of the substrate board. This very unique product structure is spreading its application possibilities into many areas beyond the original printing world. This is due to the ability to monitor the heating element temperature in real-time as well as to sense the actual media temperature as it is heated.

As it can be seen from the comparison matrix, the new heating head has a simpler substrate structure and easier to manufacture or better manufacturability and also the heating surface can be over-coated with materials of various characteristics, including lower coefficient of friction.

References

[1] H. Taniguchi, S. Sunada, J. Oi, NIP & Digital Fabrication Conference **2013**, pp. 130-134

[2] H. Taniguchi, S. Sunada, J. Oi, M. Tatsuya, NIP & Digital Fabrication Conference **2014**, pp. 65-68

Author Biography

Before founding HIT Devices Ltd., in Kyoto, Japan, Hideo Taniguchi worked for ROHM Co., Ltd. for over 40 years where he was responsible for the products including items relevant to the printing industry like thermal printheads (printhead with partial glaze layer, development / implementation of driver ICs on substrate for printhead) and development / mass-production of LED printheads. He received his BS from Ritsumeikan University in Kyoto (in the field of Applied Chemistry) with additional study in Electrical Engineering.

Shigemasa Sunada joined HIT Devices Ltd., in 2007 and has been working in various heating head projects for design and development. Prior to his current work, he worked for ROHM Co., Ltd. in Kyoto as a design and development engineer for such products as LEDs and various diodes. He graduated in mechanical engineering at Rakuyo Technical High School in Kyoto.

Jiro Oi works for HIT Devices Ltd., a Kyoto-based electronic component manufacturer. A native of Hokkaido, Japan and now he resides in Brentwood, Tennessee. Prior to joining HIT Devices, he worked with ROHM Co. Ltd. for more than 15 years specializing in thermal printheads and other electronic components. He received his BSEE from California Polytechnic State University in San Luis Obispo, California and MBA from Thunderbird School of Global Management in Glendale, Arizona.

Mark Tatsuya has worked for HIT Devices Ltd as a marketing manager since 2012 to develop new markets. Prior to joining HIT Devices, he worked for Rohm Ltd for over 15 years, and then worked at Torex Semiconductor Ltd specializing in power management ICs for another 15 years. His expertise is marketing and sales engineering with extensive experience in global sales. He received his Bachelor of Science in Physics from Kyoto Sangyo University.