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DUAL EFFECT COOLING SYSTEM FOR THERMAL INKJET PRINTHEADS

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Dual effect cooling system for Thermal Inkjet printheads

Abstract.

Thermal Inkjet (TIJ) printheads are a core technology for some printing businesses, and are used both in large format printers and 3D printers. TIJ printheads work by applying energy in the form of heat to a fluid, producing a bubble that grows, ejecting a drop. Part of this heat is removed from the printhead as it travels with the drop ejected, but some of the heat remains in the printhead. If the job to be printed has a high printing density, the amount of heat that is generated and accumulated in the printhead is high. This effect is accentuated if the firing takes place in a highly demanding environment as a 3D printer. Under these conditions, the amount of heat that is generated is a hard limitation to the printing speed, as well as to the breadth of materials that can be fused in the printer. In this document, a solution to reduce the amount of residual heat accumulated in the printhead is presented.

1 Problem

Thermal Ink Jet printheads are complex mechatronic systems in which heat management plays a key role for correct functionality, due to the inherent thermal nature of the technology. In order to create a drop, a water based ink or agent is nucleate boiled, with the objective of creating a bubble that is capable of ejecting a drop on its collapse. Part of the heat that is necessary to create the drop is removed from the printhead as it travels with the drop ejected, but some of the heat remains in the printhead.
In printers in which the printheads work in a relatively cold environment, the heat that is ejected with a drop represents a significant part of the total heat generated, and since there is no other major source of heat, the heat that remains in the printhead doesn't often represent a problem. On the other hand, in systems such as 3D printers, the environment in which printheads work is thermally highly demanding, due to a combination of different factors:

- The face of the printhead where dies are placed (front side), is exposed to the printing chamber, which can be at temperatures of over 90 Celsius.

- The front side of the printhead is exposed to a hot bed, which transmits heat to the dies by radiation in the moment of printing, which is, incidentally, the most critical moment from a thermal point of view.

- Printing rates are usually high, which means that the firing frequency is bound to be high, which has a direct impact on the amount of heat that is generated inside the printhead.

These factors make the temperature of the dies raise over reasonable working conditions, during long period of times, and this has a negative impact on:

- Printhead reliability: There are some adhesives inside the printhead that deteriorate with high temperatures, producing cross contamination of fluids inside the printhead, among other negative effects.

- Speed of the printing process: In order to achieve high printing speeds, the firing frequency needs to be increased, but it can only be increased up to a certain frequency as it has a direct impact on die temperature.

- Materials breadth: Some materials need higher temperatures to be fused. There are some materials that cannot be included in the materials portfolio, in part, due to a lack of thermally capable printheads. Besides this, in printers that work with latex inks, dies overheating represent a problem as it produces crusting and also impacts negatively on color consistency.

2 Prior solutions

Some solutions given to this problem are related to limiting the firing frequency. By reducing the firing frequency, the amount of heat that is generated decreases significantly, but it also limits the speed at which the carriage can travel, leading to reduced printing speeds.
Another solution available is macro-recirculation, which consists of recirculating the ink inside the die, using the ink as a coolant fluid. This solution has proven its validity, but has a very limiting drawback: it reduces the number of colors available in a printhead, as it needs two channels dedicated to one single color.
Other solutions consist of blowing air directly onto the dies, removing heat by convection. This solution helps the die to cool down, but it is difficult to integrate in a 3D printer without blowing air inside the chamber, an effect that has negative effect in the printing process, as it makes more difficult to manage heat inside the printer. In addition, this cooling effect only happens in the servicing station and not while printing.
Another way of removing heat from a printhead consists of blowing air to the body of the printhead.

3 Dual effect cooling system

3.1 Apparatus

The device consists of two main hardware parts:

1. *Top*: It is a 3D printed module that has built-in fittings for the pipes. Alternatively, it can be built in plastic injection molding.

2. *Body*: It is built in machined aluminum. These two parts form two differentiated circuits along which energy in the form of heat is exchanged.

There is one circuit (body of the heat sink), in which a refrigerant fluid enters at low temperature and leaves at higher temperature, as it absorbs heat from both the body of the printhead, and the ink. The inlet and outlet of this circuit correspond to the fittings of higher diameter in figure 1a.
There is a second circuit, embedded in the first one, in which the ink enters at high temperature and leaves at lower temperature. The ink circuit is composed of pipes that are attached to the lower diameter fittings shown in figure 1a.
The union between the body of the heat sink and the printhead is made of thermal rubber, allowing for heat conduction.

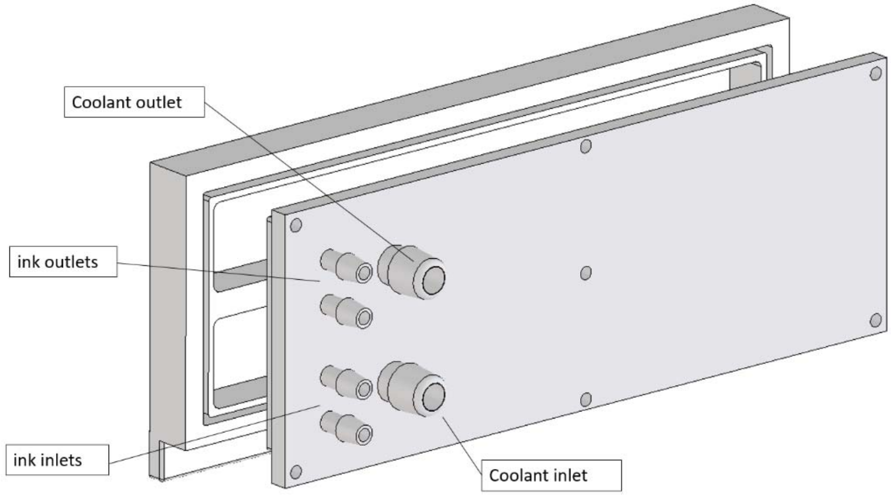

Figure 1a. Front view of the device

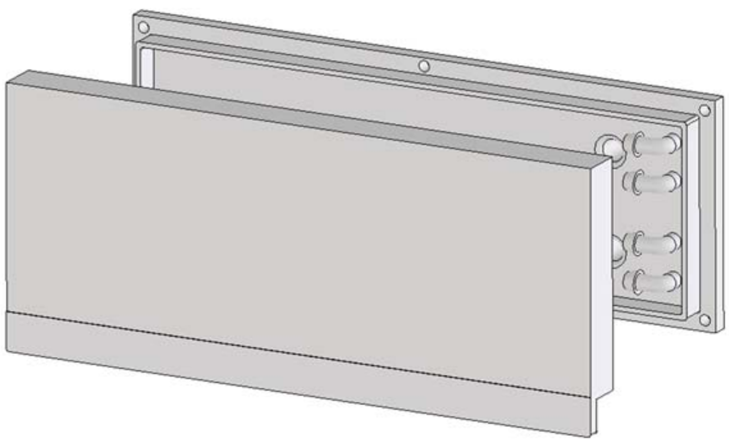

Figure 1b Rear view of the device

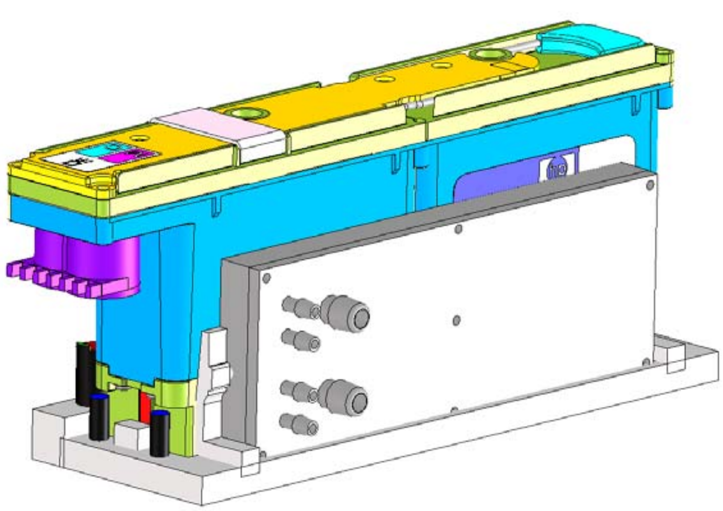

Figure 1 Integration of the system in a pocket with a printhead

3.2 Method

The solution proposed in this document is capable of cooling down the printhead, by a combination of 2 simultaneous effects:

1. **Cooling down the ink that gets delivered to the printhead. This effect would be negligible when the amount of ink released is low, but substantial when the amount of ink is high, which is, incidentally, the most thermally critical moment for the printhead. The heat is removed from the inner part of the printhead, as the ink is in contact with the ceramic layer underneath the dies (MLC), which gets to very high temperatures. This is assumed to be the best way of removing heat from a printhead.**

2. **Cooling down the outer part of the printhead by conduction, especially the lower part of the printhead, very close to the dies, where the temperature reaches high values.**
   The coolant can be cooled down by an external chiller. Figure 1c shows an example of an integration of the device, adapted for a printhead in a pen pocket.

4 Advantages of using this method and apparatus

The solution proposed in this document will allow the removal of heat from the die and from the printhead in general. This has direct impact in two highly sensitive variables of the 3D printing process:

- **Printing speed: It will allow for higher carriage speeds, as printheads overheating represent a limitation to printing speed. This will ultimately have an impact in throughput.**

- **Materials breadth: It will allow for higher materials breadth, as printheads overheating is a current limitation for new portfolio materials.**

- **Printhead reliability: It will positively effect printhead reliability, as it reduces the thermal stress, increasing life of the printheads, which are an expensive part a printing system.**

Also, printhead thermal uniformity can be easily achieved, as the energy removed from the printhead can be controlled by means of two variables: flow of refrigerant and temperature of refrigerant. On top, it is easy to integrate in the machine and doesn't need changes to the printhead architecture. This permits its use in any kind of printhead available.

If used in printheads that work with latex inks, it will help to fight crusting, and it will contribute to better color consistency.

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6