FUJIFILM Dimatix's Energy Dissipating Technology

Electric fields are used to actuate jets in Piezoelectric printheads. The forces resulting from this actuation, even when carefully controlled, can have undesirable side effects that can be detrimental to printing performance. For example, when each jet fires, it expels fluid from the printhead, which must be refilled for future jetting. The forces that drive the refilling process generate low frequency energy that is trapped inside the printhead. If this energy is left unchecked, it would disrupt jetting consistency. FUJIFILM Dimatix's MEMS printheads use Dimatix's energy dissipation technology to absorb and remove a large portion of this low frequency energy in a very interesting way that might surprise you.

A meniscus is the curved surface of a liquid in a tube. It results from surface tension, channel surface energy, and pressure differences.

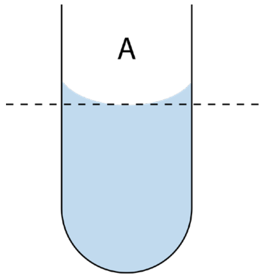

Figure 1: An example of a meniscus.

Figure 2: Varying menisci positions and varying drop sizes.

A meniscus exists at each nozzle in a printhead at the boundary between the jetting fluid and the outside air. The position of the meniscus affects the jetted drop's size, and the jetted drop's size affects image characteristics.

The low frequency energy discussed above that results from refilling affects the position of the meniscus. So, if this low frequency energy trapped inside the printhead is not controlled, it can vary over time causing the meniscus position to vary over time and, consequently, the drop size could vary over time. This typically could result in inconsistent print quality. To ensure a consistent meniscus position, low frequency energy must be kept consistent over time, and a good way to maintain consistency is to simply keep that energy level low.

One of the challenges in removing low-frequency energy is doing it in a way that does not inadvertently affect the high frequency energy that is relied upon to drive jetting. FUJIFILM Dimatix has developed a clever, multi-pronged strategy to combat low-frequency energy in a way that has no significant detrimental effect on high frequency jetting.

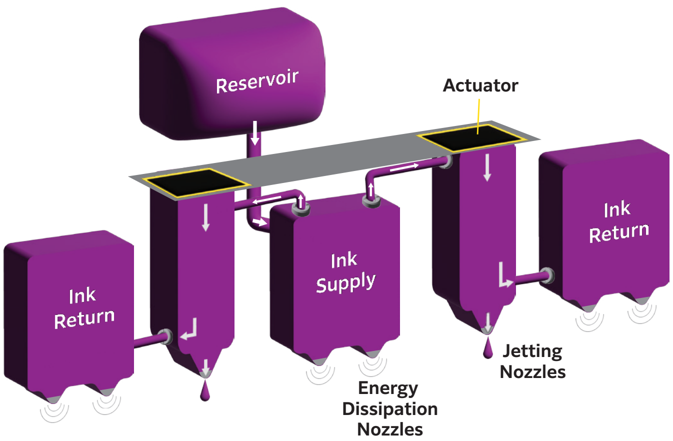

Figure 3: Jetting and refilling

When ink is jetted, the inside of the printhead must function as if it is sealed. Similarly, gunpowder can only propel a bullet when it is sealed inside the bullet's shell casing in the gun barrel; this focuses the energy of the gunpowder into the bullet. Gunpowder placed on a dinner plate and lit would only burn and not propel the plate or much of anything else.

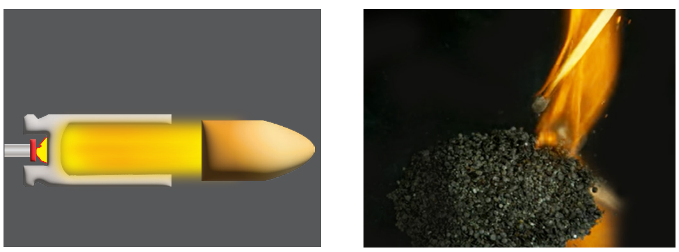

Figure 4: Gunpowder during gunfire (left) and loosely placed and lit with match (right).

A problem however with having the printhead nearly sealed for jetting is that in that state, it cannot receive new ink to refill what is lost through jetting; this would be like trying to fill a bottle of shampoo while at the same time squeezing shampoo out. To resolve these conflicting constraints, Dimatix's MEMS printhead technology jets and refills ink on very different time scales. This enables the printhead to function as if it is mostly sealed for jetting and function as if it is open for refilling; even though both functions are essentially happening at the same time!

It might seem counterintuitive that something can function so differently on two different time scales, but there are examples in our daily lives where this can happen. You may have experienced a car breaking down on the highway. After the car is safely stopped, it is possible to roll the car off the road by putting it into neutral, releasing the brake, and pushing it very slowly. Sometimes your friend might need to help push, but it is possible in this way to move a car as heavy as two tons.

Figure 5: The timeframe of energy applied to push a car is different than that of hitting it with a hammer resulting in different effects.

FUJIFILM Dimatix's Energy-Dissipating Technology

The key is to push with great force but very slowly while building up momentum. This is very different than swinging a sledgehammer at the car. A sledgehammer imparts great force and would likely dent the car or worse, but it won't move the car. The force of the sledgehammer is applied over a much shorter timeframe. The push of the car and the swing of the sledgehammer could occur at exactly the same time on the same car and would have entirely different, independent effects.

It is this same principle of multiple time domains that enables the first aspect of FUJIFILM Dimatix's multi-pronged strategy of dissipating low frequency printhead energy: jet on one time scale, while refilling over a very different time scale.

The second element of FUJIFILM Dimatix's strategy to manage low-frequency energy is to establish a large fluid volume inside the printhead. This is because a large fluid volume will absorb more energy than will a small volume of fluid.

Printhead designers want the printhead's fluid volume to be as large as possible compared to the forces resulting from unwanted low frequency energy. The problem is that creating a large fluid volume in the printhead would use up valuable space needed for the intricate printhead design features, or it would simply increase the size of the printhead too much to be practical or cost effective in printing machines. Thus, designers came up with a way to make the fluid volume behave as if it were large while being small.

The easiest way to do this is by using flexible, non-rigid walls within the printhead structure.

A small structure with flexible walls will respond to energy input more like a large structure because, when perturbed, the fluid can simply push out against the walls that confine it. Printheads such as Fujifilm's STARFIRE® class use soft membranes as flexible walls which work extremely well to accomplish this objective.

For FUJIFILM Dimatix's MEMS printheads however, inserting a flexible membrane is more difficult. Inserting soft membranes into the MEMS die is not practical because such soft components cannot survive the intense manufacturing conditions when using silicon die manufacturing. This limits the designers' options and makes the challenge even greater: we need a small, highly rigid structure to look large from a fluid perspective. What's the one thing inside a printhead that's flexible, and isn't present during manufacturing? The fluid the printhead will be jetting!

Ink, like all liquids, has a surface tension at the meniscus as we discussed earlier. Insects can land on and walk on the surface of water without sinking.

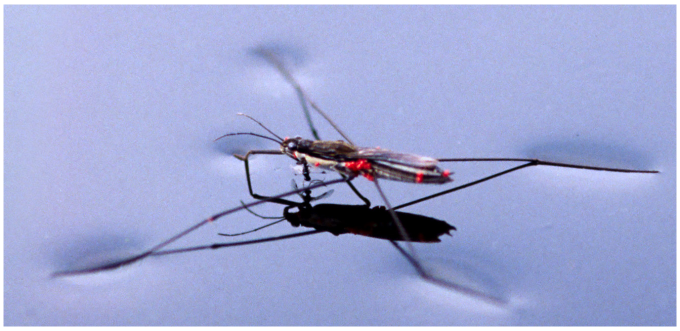

Figure 6: Insect landing on water.

This is because the surface of water has a springy property that can hold up light objects like insects. But, the menisci of jets in the printhead are busy jetting, so they cannot be used as a flexible membrane. The menisci of inkjets are like membranes that are continually and intentionally breaking every time they jet ink. To solve this, we need menisci that are not involved in jetting; hence FUJIFILM Dimatix designed non-jetting holes into its MEMS printheads to expose ink to the outside air enabling the formation of menisci that can act like a flexible membrane (Figure 7). If you observed these in slow motion while the printhead is jetting, you would see slight oscillations of the liquid as fluid menisci flex and absorb low frequency energy.

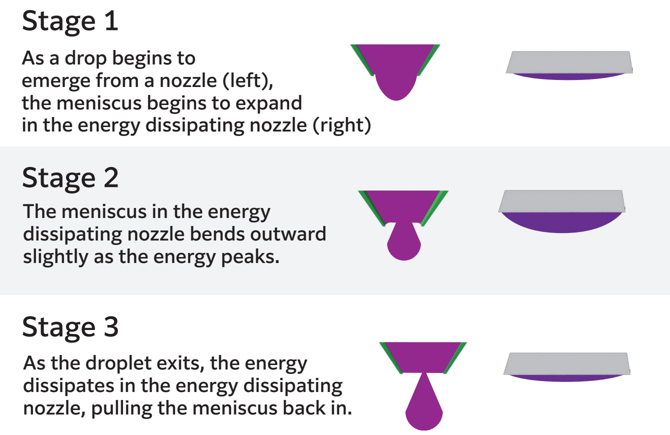

Figure 7: Stages of motion of energy dissipating menisci

Conveniently, the same methods used to manufacture the jets in the printhead can be used to produce these non-jetting openings.

The energy dissipating "nozzles," are carefully designed to ensure they do not jet, support thorough recirculation, do not leak, and provide sufficient energy absorption for the amount of low frequency energy that must be dissipated. FUJIFILM Dimatix's printhead designers must also consider the effect on increased evaporation from ink resulting from exposing more fluid to the outside air. By leveraging the use of jetting features in the silicon MEMS die as the means of energy dissipation, FUJIFILM Dimatix obtains incredibly tight control over the shape and configuration of these nozzles. This enables balancing these various considerations into an overall design that optimizes performance.

The phenomena inside piezoelectric printheads is incredibly complex, and the interrelationships involved among these phenomena are staggering. Amidst this, FUJIFLM Dimatix finds clever ways to solve problems. Like any great technology, until the underlying science is fully understood, it almost looks like magic!

FUJIFILM Dimatix SAMBA® 1200 dpi printheads are leading the world in industrial high-performance printing for the world's most demanding printing applications. FUJIFILM Dimatix SKYFIRE® opens new possibilities for printer developers seeking the performance of sputtered PZT for ultra-high speed, high laydown, and high standoff 600 dpi applications.