The Femto Slider in Hitachi Hard Disk Drives

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Hitachi Leads the Disk Drive Industry with the Introduction of Femto Sliders in 2003

"The tremendous revolution in hard disk drive storage technology over the past half century has been led by miniaturization of every component in the system. That trend continues with the introduction of the 'femto' slider, which represents a key advancement in magnetic recording technology. Hitachi's implementation of the 'femto' slider will enable significant improvements in manufacturing productivity, disk storage capacity, and mechanical performance."

Dr. John Best, Chief Technologist
Hitachi Global Storage Technologies

The 2.5-inch Travelstar® 7K100 and the 1.8-inch Travelstar® C4K60 slim with optimized femto actuator/suspension design

Miniaturization of the femto air bearing slider in three generations of the Hitachi Microdrive®

Motivation for continued reduction in slider form factor

Technological advances in the highly competitive disk drive industry have fueled the escalating growth in areal density from a compound annual growth rate (CAGR) of 25% in the 1980ís to its current CAGR of nearly 100% (Figure 1). Achieving such high areal density magnetic recording requires extremely small and constant spacing between the air bearing slider (ABS), which carries the recording element, and the magnetic disk. At the same time, physical contact between the slider and the disk must be minimized under an increasingly demanding variety of operational and environmental conditions. The move to smaller and smaller disk drives has placed increasing demands on power consumption, shock performance, and disk storage capacity (disk real estate utilization).

Figure 1: Historical growth in areal density (CARG)

One of the key contributors to achieving these demanding requirements has been the reduction of the size of the slider by 3x, and the mass of the slider by over 30x (from 1980–2002). Reduced slider size and mass leads to a concurrent reduction of suspension size and mass that supports the slider. The combined slider and suspension mass reduction improves shock resistance, reduces power consumption and improves disk storage capacity. The reduced slider size improves the response of the slider to disk waviness, thus reducing the flying height variation of the slider in the disk drive. These advantages coupled with an integrated slider-suspension design, have been instrumental to achieving a 10x reduction in flying height over this same period. Figure 2 shows the new femto slider compared to its pico predecessor.

Figure 2: The pico and femto sliders, attached to their suspensions, are circled and shown for comparison. The pico unified arm assembly is shown on the left and the femto HGA (not attached to its arm assembly) is shown on the right. The HGA portion of the pico unified arm assembly is identified in brackets for comparison to the femto HGA, also shown in brackets.

Another benefit of a reduced slider form factor is manufacturing efficiency. By putting more sliders on a wafer (Figure 3), wafer productivity for the slider manufacturer is significantly improved and cost is reduced.

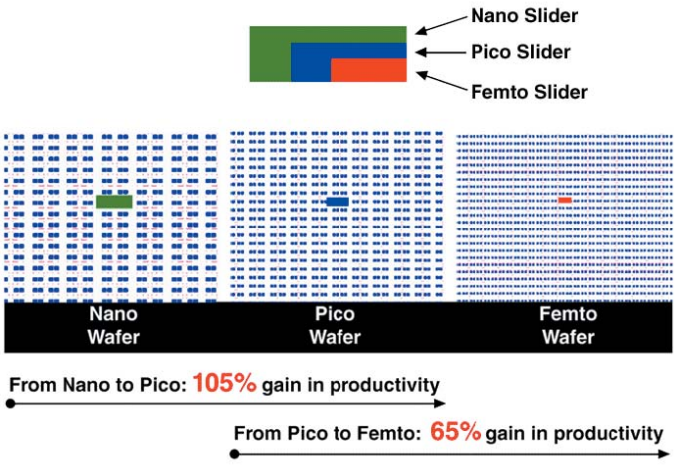

Figure 3: Increased slider packing density per wafer (end view of slider body shown for reference)

In 2003, Hitachi's Travelstar 7K60, a 7200 RPM, 2.5-inch hard drive series which offered 60GB of storage capacity, was the industry's first disk drive product to utilize femto sliders. The reduced slider size (mass), the femto air bearing slider design, and the femto suspension design resulted in improved shock performance, reduced power consumption, and improved storage capacity per disk surface (Figure 4).

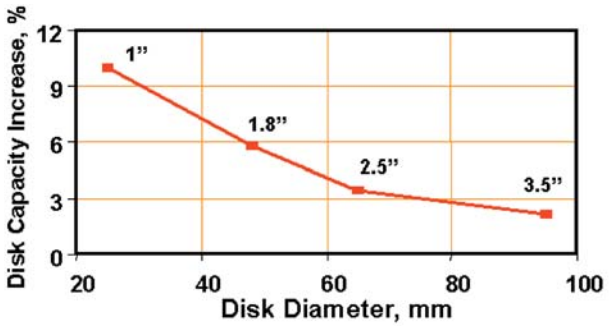

Figure 4: Smaller slider opens up a greater percentage of the disk surface available for recording. The narrower width of the femto slider allows the assembly to get closer to the outer diameter of the disk surface making more surface area available for data recording.

Slider form factor history

Table 1 shows a historical overview of the slider form factor. The femto slider represents the next step in the evolutionary process of reducing size and mass to achieve smaller form factors and improve manufacturing efficiency. The femto slider reduces linear dimensions by 30% and mass by 63% compared to the current pico slider.

Travelstar 7K60 first generation femto air bearing slider

The femto air bearing slider design for the Travelstar 7K60 is shown in Figure 5. It had three surfaces, each specifically designed to achieve the overall desired air bearing slider performance characteristics. These include a flat fly height profile across the disk, a tight flying height distribution, and minimal fly height loss at high altitude conditions. The shallow etch surface forms a step height inlet allowing airflow to pressurize the ABS surface. This results in the ABS surface generating positive pressure that lifts the slider and its magnetic element away from the disk surface. The deep etch surface forms a negative pressure pocket that pulls the slider closer to the disk

	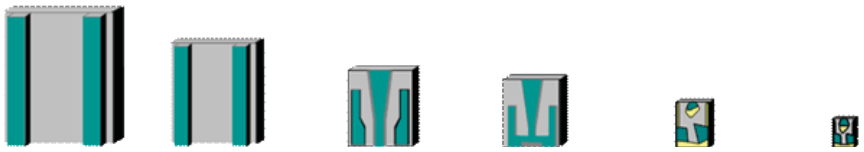					
Slider Size	Mini 100%	Micro 70%	Positive Pressure Nano 62%	Negative Pressure Nano 50%	Pico 30%	Femto 20%
Intro Year	1980	1986	1991	1994	1997	2003
Dimensions, mm						
Length	4.00	2.80	2.50	2.00	1.25	0.85
Width	3.20	2.24	1.70	1.60	1.00	0.70
Height	0.86	0.60	0.43	0.43	0.30	0.23

Table 1: Slider form factor historical overview

surface. These positive and negative pressure regions are designed to balance the downward force of the suspension gram load in a way that lifts the magnetic element to the desired fly height. These pressures are also designed to create a high stiffness air bearing that reduces flying height variations due to manufacturing tolerances, as well as operational and environmental variations.

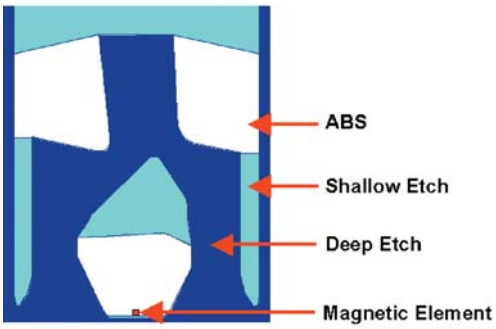

Figure 5: Travelstar 7K60 air bearing slider design

The Travelstar 7K100 family employs an optimized femto actuator/suspension design based off the Travelstar 7K60 architecture to achieve 100GB of storage capacity and a 50% improvement in operating shock. The enhanced femto air bearing slider also contributes to reduced power consumption by the 7200 RPM, Travelstar 7K100 drive while boosting areal density over 47% to achieve 81 Gbits per square inch on 2.5-inch disks.

The smaller slider size, compared to pico sliders, reduces the positive and negative pressure of the femto slider by a factor of two. The significantly reduced mass and pressures permits improved shock resistance and lower power consumption (Figure 6). The benefits afforded by femto air bearing slider technology are especially suited for hard drives that are integrated into portable and handheld applications, leading to its usage in the Hitachi Microdrive 3K4 series in late 2003, and most recently the Microdrive 3K8 in 2005.

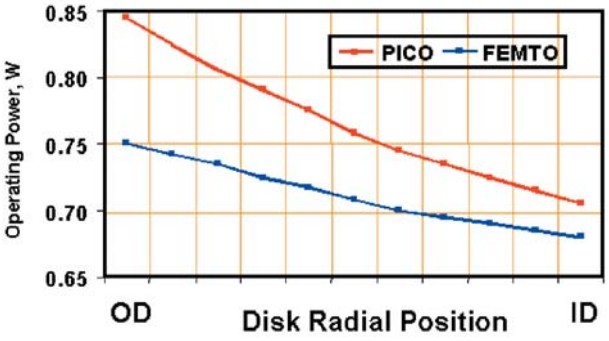

Figure 6: Power consumption, pico vs. femto

The founding Travelstar suspension design

The air bearing slider is attached to a suspension, which supports the slider as it flies over the disk surface. This system is called the head gimbal assembly (HGA). The suspension size, mass, and design are greatly influenced by the reduced size of the femto slider. The reduced size of the femto slider allows the suspension designer to reduce the size (and thus the mass) of the suspension (Figure 2). The femto suspension was carefully designed to insure that its performance characteristics were carefully matched to those of the femto air bearing slider (ABS). As a result, the reduced mass HGA has improved mechanical performance in such areas as shock performance of the disk drive and HGA dynamics. Reducing the size of the femto slider would normally result in the slider having an increase in the flying height variation. However, the Travelstar 7K60 suspension design reduced the suspension stiffness to insure the flying height variation remains essentially the same as pico.

Conclusion

The implementation of the femto slider in the Travelstar and Microdrive products continues Hitachi's ongoing strategy to provide improved disk drive performance through innovative technology. It is anticipated that the benefits of shock resistance, power consumption, and disk capacity will facilitate the use of femto sliders in all drive segments including those not typically used in portable applications such as 3.5-inch desktop and enterprise server hard disk drives.

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