A Quest for Spindle Speed Using a Multi-Physics Motor Design Tool

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The Opera motor design software package is helping Air Bearings of Poole to extend the speed of spindle motors beyond 400,000 RPM. The package's integrated electromagnetic and thermal simulators are being used to identify optimizations that will make the motors more compact and efficient, to improve rotational speeds beyond their current maximum.

Owned by Hitachi, Air Bearings Ltd of Poole (UK) is a world leader in ultra-high-speed drill spindles for manufacturing printed circuit boards (PCBs). Air Bearings' products are a key element of the world's most popular PCB drilling machines from Hitachi Via Mechanics - which drill connection vias and holes at speeds of over 10 holes/second.

Advances in PCB drill spindle motors almost invariably rely on increasing rotational speed, to improve drilling productivity and quality. Up until 2010, the Air Bearings Ltd (ABL) design team generated new motor designs using principles and know-how of air-bearing-equipped motors that had been acquired and proven over decades of business. The development process usually involved making a number of prototypes, and the team typically delivered a couple of new motor designs every year.

However, as spindle speeds increase - which over the last decade have escalated from around 80,000 to 350,000 RPM - the design challenge has become tremendous. Increasing rotational speed depends largely on reducing rotor mass. To achieve this, Air Bearings has started to extend the motor technologies it employs to improve efficiencies - from AC induction motors to permanent magnet types - and to explore the value of being able to optimize a much wider range of design parameters.

CAE tool support is viewed as essential for this more complex design environment, and ABL compared several electromagnetic simulation software packages including Opera from Cobham Technical Services - Vector Fields Software. Given the company's focus on pushing motor performance to its absolute limits, the fidelity of

the simulation process was essential, and ABL took the unusual step of comparing software design packages by correlating their predicted results against the known performance of existing motors.

"We looked at four packages. Only two of them gave us the very high simulation accuracy we needed, and of these, we chose Opera because it offered the most modeling flexibility," says Neil Russell, ABL's R&D Manager. "The design automation now gives us great confidence that we can improve design throughput substantially, by between five- and ten-fold, with the same headcount."

Opera's optimization capabilities are being employed to help ABL make the optimum design choices, helping the designers to minimize losses. The integrated thermal modeling capability also gives the team the ability to predict temperature changes of the air-bearing-mounted rotor - something they have not been able to achieve previously with real-world measurements. Controlled temperature performance is particularly important, because at 400,000 RPM the rotors are at their extreme limits mechanically. Opera's integrated electromagnetic and thermal solvers are also particularly helpful in predicting and minimizing harmonic losses - which can be substantial in such high speed motors because of their solid, non-laminated, rotor construction.

One other area of optimization that Opera is making possible, is the calculation and elimination of stray losses from induced eddy currents in metallic components such as screws and rivets that are in close-proximity to rotating permanent magnets.

"Simulating these high speed motors is very demanding. Special finite element meshing techniques available in Opera assist ABL in accurately modeling and predicting the losses, and consequent temperature rise," added Chris Riley of Cobham Technical Services - Vector Fields Software. "Dynamic simulations coupled with circuit analysis are also vital for the very fast switching speeds required for the new motor configurations ABL is developing. Opera-based simulation is proving to be a reliable tool for modeling the interaction of the machine and its drive system."

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