Stepper Motor Actuators

THE QUESTION

How would you compare the efficiency and capabilities of hybrid stepper motor actuators vs. can stack stepper motor actuators?

Figure 1 Laminated steel stator assembly.

Figure 2 Stamped low-carbon steel field ring.

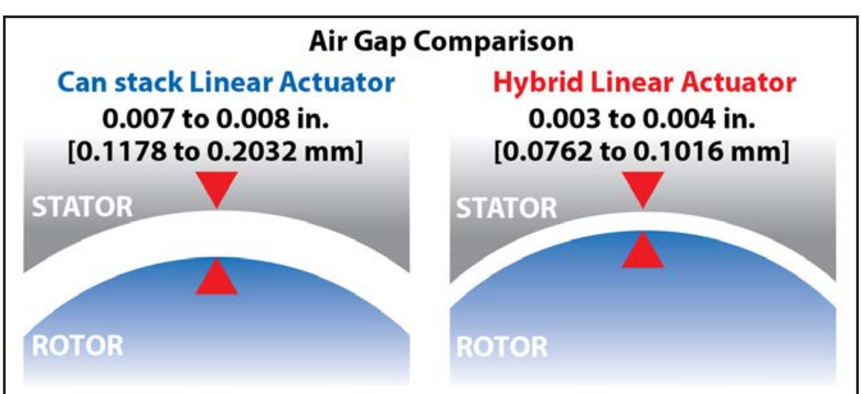

Figure 3 Air gap comparison can stack vs. hybrid linear actuators.

Expert response provided by Ray LaChance and Joe Rossi, Haydon-Kerk Motion Solutions

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The answer to this question can be found in the efficiency of the motor itself. The average hybrid motor is about 65% efficient while the can stack actuators average about 25% efficiency. There are two primary reasons for these differences in efficiency.

The first reason is the use of a laminated silicon steel stator assembly in the hybrid motor (Fig. 1), compared to a stamped low-carbon steel field ring assembly in the can stack motor (Fig. 2). The use of a laminated stator stack in the hybrid motor construction results in less eddie current loss and the silicon steel material used in the lamination construction reduces hysteresis loss. Therefore the total iron loss in the hybrid motor is less than the can stack motor, resulting in the hybrid motor's higher efficiency. series, i.e. — 1.8 degree/step and .9 degree/step (vs. 7.5 or 15 degrees for the typical can stack) will allow resolutions down to .000060 in. [0.001524 mm]/full step compared to .00025 in.[0.00635 mm]/full step in a can stack motor. Therefore the hybrid motor provides much finer positioning capability.

The second advantage is within the motor's magnetic circuit. The construction of the hybrid motor actuators allows for the air gap between the rotor and stator assembly to be about one-half of what the can stack motor actuator can be manufactured to. The air gap in the hybrid design is typically 0.003 to 0.004 inch [0.0762 to 0.1016 mm], compared to 0.007 to 0.008 inch [0.1778 to 0.2032 mm] in the can stack construction. The smaller air gap provides a more efficient magnetic coupling between the rotor and stator, resulting in higher torque (Figs. 3 and 4).

Comparing the size 17 single-stack hybrid actuator (1.7 in.^{2} [43 mm^2]) and the 46000 can stack actuator (Ø1.8 in. [Ø 46 mm]), 7 watts and 10 watts of input power respectively, with the identical lead screw; the resulting force at the same linear velocity is much higher in the hybrid version (Fig. 5).

In addition to the efficiency advantages shown above, there are other advantages that the hybrid actuators have over the can stack versions:

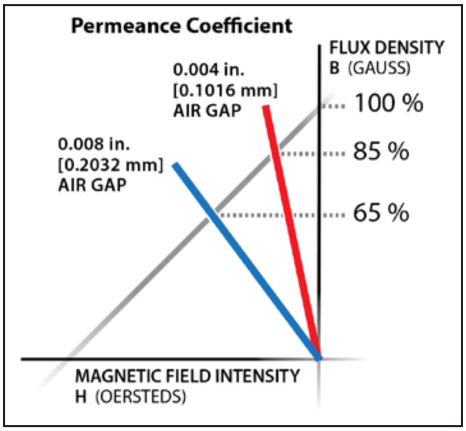

Figure 4 Effect of air gap on motor efficiency and performance.

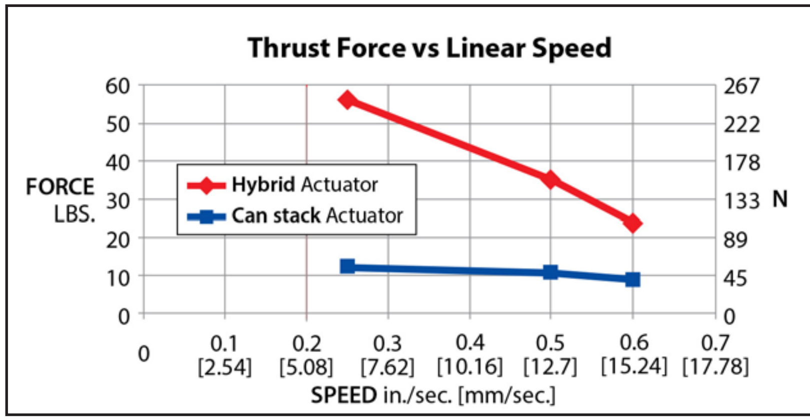

Figure 5 Comparison curves.

1. Stepper motor-based linear actuators are extremely useful in positioning applications, whereas linear motion occurs for every pulse sent to the motor's controller. The resolution of this motion is a function of the lead of the screw and the degrees-per-step of the stepper motor. The step angles available in the hybrid series — 1.8 degree/step and .9 degree/step (vs. 7.5 or 15 degrees for the typical can stack) — will allow resolutions down to .000060 in.[0.001524 mm]/full step compared to .00025 in. [0.00635 mm]/full step in a can stack motor. Therefore the hybrid motor provides much finer positioning capability.
2. Mounting of the actuator can play a critical role in overall system performance in many applications. The hybrid actuators have a locating boss on the front-end bell that is concentric to the motor bearings, thus allowing better mounting to center the actuator in the assembly (Fig. 6).
3. The ability to add encoders for closed-loop operation is easily performed on the hybrid line of actuators due to its use of a metal rotor insert compared to the plastic rotor journal used on the can stack actuators. The brass rotor insert can be machined to a tight tolerance, enabling it to have greater mechanical strength and a precise fit through the motor bearings, resulting in less run out of the encoder wheel and a more reliable encoder count when using high-resolution model encoders.
4. An increase in output power may become necessary for any given application. The hybrid motor construction allows for several output power levels for a given frame size. Its output power can be increased by creating a longer stator

stack and rotor assembly. This can be achieved at a reasonable cost. To do this on a can stack motor would involve a complete retooling of the motor that comes at considerable cost due to capital investment.

As outlined above, the hybrid stepper motor's higher efficiency — due to lower iron loss and smaller rotor to stator air gap — offers a higher output power density when compared to the can stack motor. These features do come at an increased cost, but if the can stack actuators meet the required force, speed and resolution requirements it will be a less expensive solution.

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Figure 6 Locating boss feature for concentric mounting.