Sensitivity analysis of a comprehensive model for a miniature-scale linear compressor for electronics cooling

Craig R. Bradshaw\textsuperscript{a,b}, Eckhard A. Groll\textsuperscript{a,b,*}, Suresh V. Garimella\textsuperscript{b}

\textsuperscript{a} Purdue University, Herrick Laboratories, 140 S. Martin Jischke Drive, West Lafayette, Indiana 47907-2031, USA
\textsuperscript{b} Cooling Technologies Research Center, Purdue University, West Lafayette, IN 47907, USA

**Abstract**

A comprehensive model of a linear compressor for electronics cooling was previously presented by Bradshaw et al. (2011). The current study expands upon this work by first developing methods for predicting the resonant frequency of a linear compressor and for controlling its piston stroke. Key parameters governing compressor performance – leakage gap, eccentricity, and piston geometry – are explored using a sensitivity analysis. It is demonstrated that for optimum performance, the leakage gap and frictional parameters should be minimized. In addition, the ratio of piston stroke to diameter should not exceed a value of one to minimize friction and leakage losses, but should be large enough to preclude the need for an oversized motor. An improved linear compressor design is proposed for an electronics cooling application, with a predicted cooling capacity of 200 W in a cylindrical compressor package size of diameter 50.3 mm and length 102 mm.

© 2012 Elsevier Ltd and IIR. All rights reserved.

**1. Introduction**

A comprehensive simulation model for a miniature-scale linear compressor was recently developed by Bradshaw et al. (2011). The model was also validated against experiments conducted on a prototype linear compressor constructed for the purpose. It was found that the overall performance metrics predicted by the compressor model are highly...
sensitive to the leakage gap $g$, eccentricity $\epsilon$, dry friction coefficient $f$, and motor efficiency $\eta_{\text{motor}}$. Fig. 1 depicts the major components and design parameters of a linear compressor. The geometry of the piston is directly related to both the friction and leakage of a compressor. Therefore, for a fixed displaced volume, some piston diameter and stroke combinations will provide higher efficiency than others. The impact of changes to these parameters proves useful when designing a linear compressor, and warrants further investigation.

A linear compressor has two major practical limitations, which restrict its implementation in practical systems. Both the resonant frequency and stroke are sensitive to changes in geometry and operating conditions (Cadman and Cohen, 1969; Park et al., 2004; Pollak et al., 1979; Unger and Novotny, 2002). This poses a challenge not only to compressor design but also to modeling efforts. The ability to predict and control these two parameters provides a useful tool for linear compressor design efforts.

A method for calculating the resonant frequency of a linear compressor is developed here. An approach to numerical control is also provided that ensures compressor operation at the desired stroke. A series of sensitivity studies are presented, which highlight the sensitivity to leakage gap and eccentricity as well as piston geometry. Finally, an improved compressor design is formulated for an electronics cooling application using results from the model.

### 2. Resonant frequency of a linear compressor

The resonant frequency of the linear compressor depends on the mechanical springs selected in the design as well as the operating conditions. To calculate the resonant frequency of a linear compressor, the stiffness associated with both the mechanical springs and the operating conditions must be estimated. The stiffness of the mechanical springs is typically reported by the manufacturer. The stiffness associated with the operating conditions is the stiffness from gas compression. Using these stiffness values, an estimate of the resonant frequency of oscillation is obtained from the following expression:

$$\omega_{\text{res}} = \omega_0 \sqrt{1 - 2\zeta^2}$$

where the damping ratio is defined as follows (Rao, 2004).
دریافت فوری متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات