Non-dimensional Multi-objective Performance Optimization of Single Stage Thermoelectric Cooler

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Abstract. Thermoelectric devices are indeed device of future as they are green cooling devices. Tough still under research, performance of these devices is main concern to engineers for their suitability for practical use. In the present work, the two main concern i.e. Coefficient of Performance (COP) and Rate of Refrigeration (ROR) of such devices are simultaneously addressed. NSGA-II is used for finding Pareto-optimal solutions under three different settings for ambient conditions. Mathematical model is considered and effect of ambient conditions on optimal performance is also highlighted. The results of optimization are verified by theoretical governing equations for Thermo-Electric Coolers (TEC). It is concluded that Bi-Objective optimization of performance of single stage TEC is possible, relevant and have huge potential for practical use by designers of TEC.

Keywords: TEC, Practical Performance Optimization, Multi-Objective Optimization, NSGA-II.

1 Introduction

Thermoelectric generation technology, as one entirely solid state energy conversion way can directly transform thermal energy into electricity by using thermoelectric transformation materials. A thermoelectric power converter has no moving parts, and is quite, compact, highly reliable and environment friendly.
Due to these merits, this generation technology is presently becoming a noticeable research direct [4].

Thermoelectric coolers (Also known as thermoelectric refrigerators or Peltier modules) have been employed in various applications of small volume devices, typical of which are to stabilize the temperature of solid state lasers, to cool infrared detectors and charge coupled devices, and to increase the operating speed and reduce unwanted noise of integrated circuits [5]. Peltier modules have also been employed in portable cool boxes for medicine/serum transport and for picnic items storage [6].

Thermoelectric refrigeration and generation devices occupy a niche market, because they are quite and reliable and friendly to our environment. However, thermoelectric refrigeration appears to has made little impact on the domestic refrigeration market. The main factors that determine the marketability of a thermoelectric refrigerator are price and running cost, together with reliability, quietness, flexibility and temperature stability are important considerations. Price reflects the manufacturing cost, while the running cost is mainly determined by the coefficient of performance (COP) of the cooling unit. Although the COP of a Peltier module is lower than that of conventional compressor units, efforts have been made to develop the thermoelectric refrigerators to exploit the advantage associated with this solid state energy-conversion technology [7].

2 Past Studies

There has been a considerable interest during the past ten years in finding new materials and structures for use in green, highly efficient cooling and energy conversion systems [8]. A good thermoelectric material should possess large Seebeck coefficient (α), low thermal conductance (K) to retain the heat at the junction and maintain a large temperature gradient and low electrical resistance (R) to minimize Joule heating. These desirable properties are embodied in a so-called thermoelectric material property figure of merit Z. To describe material more useful method is dimensionless figure of merit (ZT), where T is the absolute temperature of interest. ZT provides a measure of the quality of such materials for applications and is defined by $ZT = \frac{\alpha^2 T}{R K}$ [8]. The increase in ZT leads directly to the improvement in the cooling efficiency of Peltier modules and in energy conversion efficiency of thermoelectric generators [10]. Much effort has been made to raise $Z$ of thermoelectric materials using various methods, so that they have some improvements in $Z$ (For example, $3.20 \times 10^{-3} K^{-1}$ at 300 K [11] and $3.99 \times 10^{-3} K^{-1}$ at 298 K [12] for the n type Bi-Te alloys and $3.70 \times 10^{-3} K^{-1}$ at room temperature [13] and $4.58 \times 10^{-3} K^{-1}$ at 308 K [14] for the p-type Bi-Te alloys). But their values are not sufficient to improve dramatically the cooling efficiency.

In addition to Thermoelectric (TE) material improvements, there are many areas in which research is continuing to improve the performance of thermoelectric cooler (TEC). An assembly technique which affects the temperature difference across the TE module is also being developed that may improve the