A design approach for integrating thermoelectric devices using topology optimization

Efficient operation of thermoelectric devices strongly relies on the thermal integration into the energy conversion system in which they operate. Effective thermal integration reduces the temperature differences between the thermoelectric module and its thermal reservoirs, allowing the system to operate more efficiently. This work proposes and experimentally demonstrates a topology optimization approach as a design tool for efficient integration of thermoelectric modules into systems with specific design constraints. The approach allows thermal layout optimization of thermoelectric systems for different operating conditions and objective functions, such as temperature span, efficiency, and power recovery rate. As a specific application, the integration of a thermoelectric cooler into the electronics section of a downhole oil well intervention tool is investigated, with the objective of minimizing the temperature of the cooled electronics. Several challenges are addressed: ensuring effective heat transfer from the load, minimizing the thermal resistances within the integrated system, maximizing the thermal protection of the cooled zone, and enhancing the conduction of the rejected heat to the oil well. The design method incorporates temperature dependent properties of the thermoelectric device and other materials. The 3D topology optimization model developed in this work was used to design a thermoelectric system, complete with insulation and heat sink, that was produced and tested. Good agreement between experimental results and model forecasts was obtained and the system was able to maintain the load at more than 33 K below the oil well temperature. Results of this study support topology optimization as a powerful design tool for thermal design of thermoelectric systems.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Department of Mechanical Engineering, Solid Mechanics
Contributors: Soprani, S., Haertel, J. H. K., Lazarov, B. S., Sigmund, O., Engelbrecht, K.
Pages: 49–64
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Applied Energy
Volume: 176
ISSN (Print): 0306-2619
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 8.44 SJR 3.162 SNIP 2.765
Web of Science (2017): Impact factor 7.9
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 7.78 SJR 3.011 SNIP 2.61
Web of Science (2016): Impact factor 7.182
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 6.4 SJR 2.835 SNIP 2.593
Web of Science (2015): Impact factor 5.746
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 6.93 SJR 3.158 SNIP 3.218
Web of Science (2014): Impact factor 5.613
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 6.59 SJR 3.06 SNIP 3.346
Web of Science (2013): Impact factor 5.261
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 5.69 SJR 2.778 SNIP 3.076
Web of Science (2012): Impact factor 4.781
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 5.5 SJR 2.416 SNIP 2.827
Web of Science (2011): Impact factor 5.106
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.531 SNIP 2.259
Web of Science (2010): Impact factor 3.915
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.992 SNIP 1.85
Web of Science (2009): Indexed yes
Scopus rating (2008): SJR 0.95 SNIP 1.206
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.168 SNIP 1.704
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.95 SNIP 1.277
Scopus rating (2005): SJR 1.02 SNIP 0.988
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.67 SNIP 0.844
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.713 SNIP 0.775
Scopus rating (2002): SJR 0.589 SNIP 0.779
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.368 SNIP 0.567
Scopus rating (2000): SJR 0.154 SNIP 0.498
Scopus rating (1999): SJR 0.181 SNIP 0.443

Original language: English
Keywords: Topology optimization, Thermoelectric devices, Thermoelectric cooling, System integration, Thermal management, Downhole electronics cooling
Electronic versions:
Soprani_et_al_2016_Full_Text.pdf. Embargo ended: 03/05/2018
DOIs:
10.1016/j.apenergy.2016.05.024
Research output: Research - peer-review › Journal article – Annual report year: 2016