High Power LED Luminaire Design

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Research Goals

• Design an FEM model of an LED luminaire, physics, and constraints, which represent the thermal process and the lighting process.
• Design and build a prototype and test different solutions (cooling structures and optical accessories).
• Compare simulation results with the results of experimental tests to validate the model.
• Use evolutionary algorithms to optimize the luminaire geometry, material, and layout.

Motivation

• Currently, 20% to 40% of the total electricity consumption is spent on artificial lighting [1], [2].
• Public lighting consumes 3% to 38% of the total energy bill of large cities [3].
• In Brazil, there are about 15 million points of public lighting [4].
• São Paulo has 53,000 public illumination points (the largest number in the world).
• A significant improvement in the illumination efficacy can provide a great impact on the world's energy consumption.
• None of the conventional light sources (incandescent, halogen, and fluorescent) have significantly improved in the last 40 years.
• It is estimated that by 2020, the simple replacement of traditional light sources with LEDs will provide:
  o Reduction of 50% of the total amount spent on electricity for lighting.
  o Decrease of 11% of the total electricity consumption.

Introduction

Thermal Management

• Problems regarding thermal management are commonly found in electronic devices.
• Heat transfer processes include conduction, convection, and radiation.

High Power LEDs

• Classification of LEDs:
  o Low Power
  • excitation current = 20 mA
  • power = 44mW
  o High Power
  • excitation current 350 mA to 1.5 A
  • power 1 W to 200 W
• To get the greatest benefit from HP-LED for lighting, some requirements must be satisfied.

Heat Transfer Methods

The heat transfer methods of some light sources

• In HP-LEDs the energy must be dissipated to the environment mainly by conduction to avoid damaging the P-N junctions [5].
• HP-LED lifetime is associated with its operating temperature and can be reduced under extreme conditions.
• A small increase in 10 °C can reduce the LED lifetime by 50% (see graph).
• In general, the HP-LED junction temperature must be maintained below 100 °C to ensure 50,000 hours of life [6].

Methodology

• Computer modeling was used as the methodology.
• Through finite element modeling software it is possible to represent the behavior of systems or phenomena.
• FEM software can help design a desired geometry and simulate a multiphysical problem.
• The model can be tested and validated to predict various situations, reducing the need for tests in real systems.

Simulation and Results

Case Study 1: tubular luminaire with one LED

• The first simulation was run with an LED inside a confinement without any type of heatsink.
• It is possible to see the temperature distribution on the surfaces of the domain.
• It is noted that the LED chip reaches about 85°C (theoretical value) in steady state.
  • An external aluminum heatsink was attached to the confinement base.
  • It is observed that the LED chip achieves a maximum temperature of 81.3°C in steady state.

Case Study 2: square luminaire with four LEDs

• A new luminaire geometry was designed as a compound of 4 HP-LEDs.
  • The LED chip reaches a maximum temperature of 91.3°C in steady state.

Practical Tests

• Two prototypes were built to validate the simulation and support practical experiments.
• In both case an HP-LED with the following characteristics was used (same as simulation):
  o 5-W LED model WUS1F-5W
  o Nominal parameters: 720 mA, 7 V, 250 lm.

Conclusion

• In the first case study, the results obtained are in reasonable agreement.

Acknowledgments

• Thanks to the IFS for the software license granted to full-time doctoral studies.
• Thanks for the financial aid provided by CAPES Foundation – Ministry of Education of Brazil through the project Science Without Borders.

Bibliography