Cost Optimization of LED Street Lighting

LED Lighting Technologies from Vestel Engineering

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With LED lighting technologies, the mechanical design of the luminaire is the most important aspect in meeting industry demands for cost and performance.

The shape of the body, type, and number of the fins on the external casing, and the selection of the casing and other materials are the main mechanical parameters affecting the cooling of the luminaire. All these parameters also affect the weight and cost of the luminaire, so mechanical optimization is critical to optimizing the product cost.

All LED manufacturers try to design smaller and more thermally effective luminaires through the use of CFD. For Vestel's Ephesus street light luminaire, FloEFD™ was used to optimize both the thermal design and to check the drag force on the luminaire when pole mounted, to ensure compliance with national standards for wind loading.

LEDs are unique amongst light sources in that they are designed to operate at low temperatures through the efficient conduction of heat away from the LED. LEDs generate little or no IR or UV, but convert only 15%-25% of the power into visible light; the remainder is converted to heat that must be conducted from the LED die to the underlying circuit board and heatsinks, housings, or luminaire frame elements in order to limit the junction temperature during operation, otherwise the light output falls [1]. In addition to reduced lumen output, excess heat directly shortens LED lifetime, and the lifetime of any control circuitry within the luminaire.

The challenge facing lighting companies is to design a luminaire that has the maximum thermal performance while minimizing the costs related to the materials used and

Figure 2. Design Steps

the mechanical design. As these are the largest overall contribution to the cost of the luminaire, there is a strong drive to minimize the mechanical cost through optimization of the thermal design.

The design goals for a luminaire should be based either on an existing fixture's performance or on the application's lighting requirements. So, the design steps start with researching existing product designs as benchmarks, used to develop a target

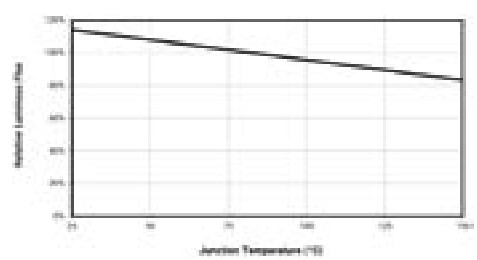

Figure 1. Relative Luminous Flux vs. Junction Temperature of White Cree XT-E (350 mA forward current)

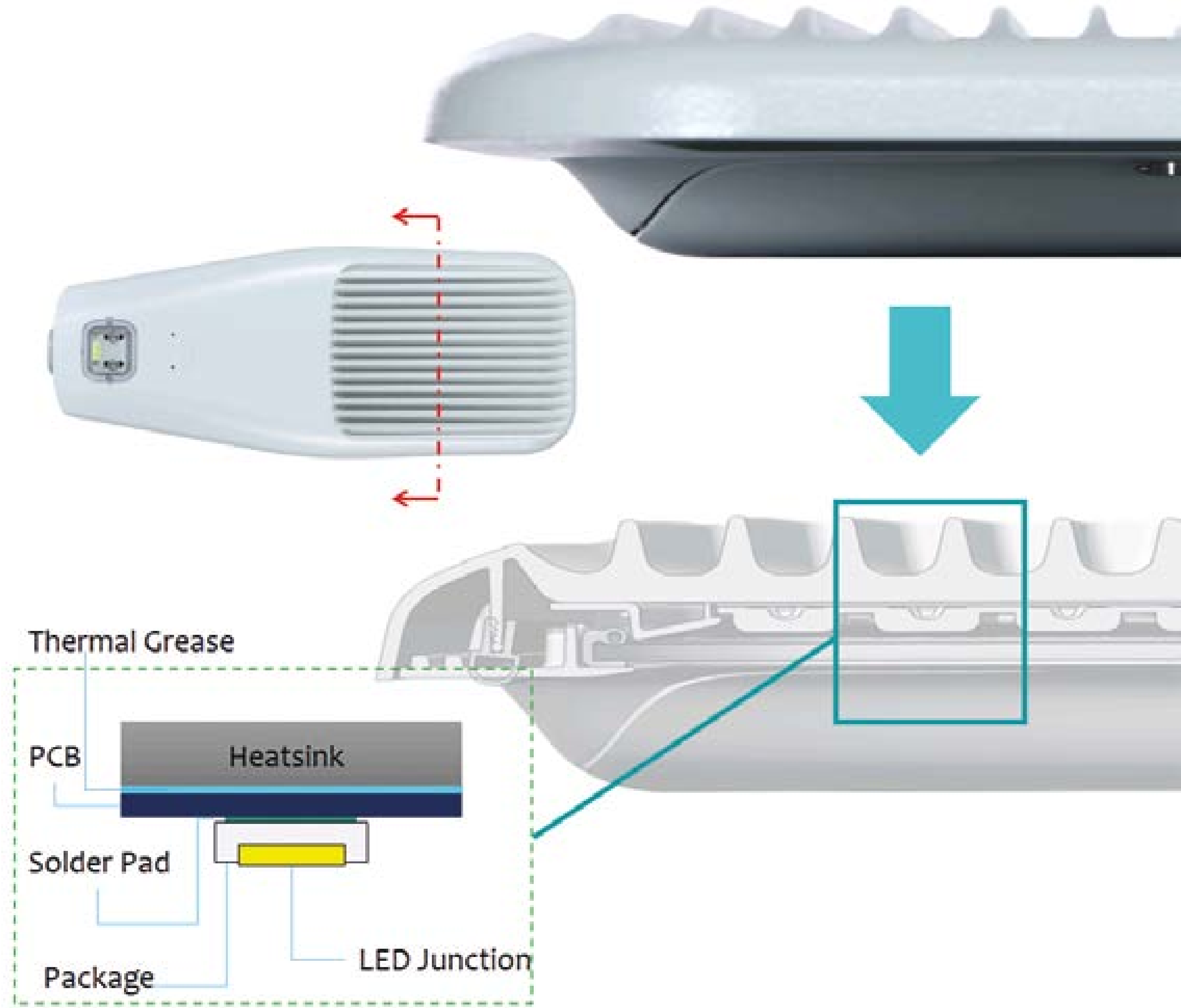

Figure 3. Cross Section of VESTEL Ephesus- Fundamental of System Configuration

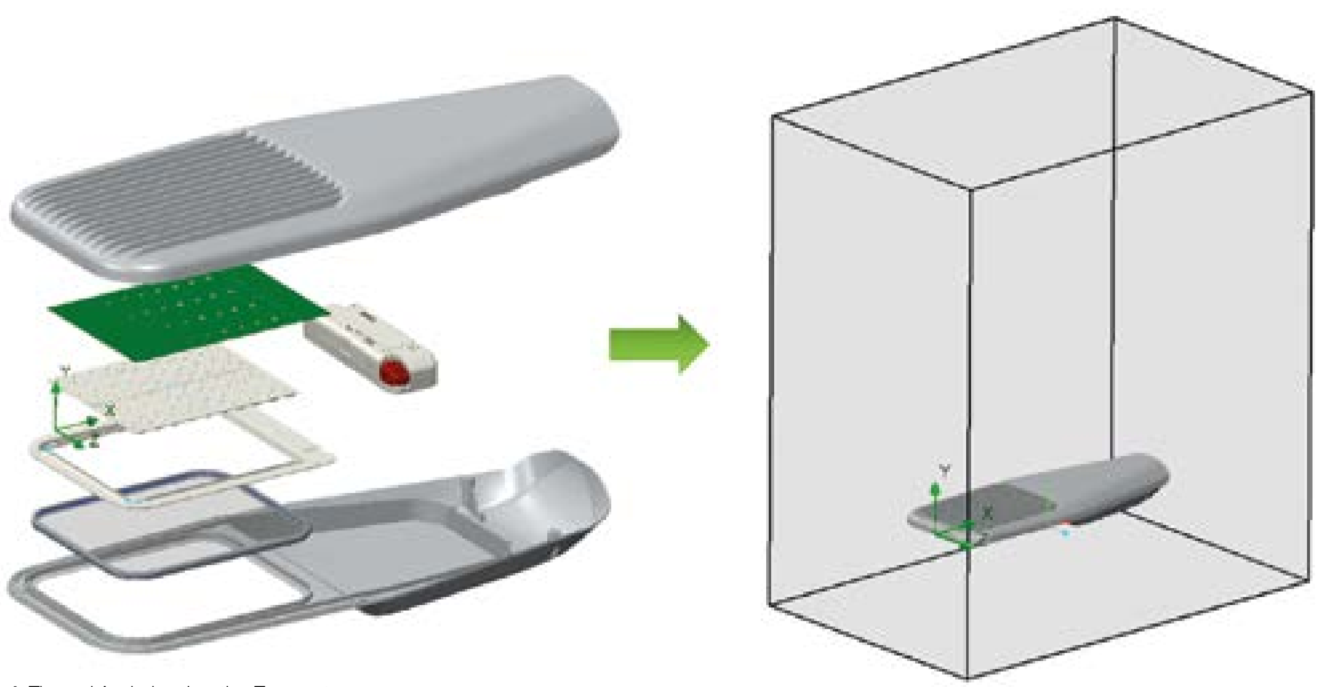

Figure 4. Thermal Analysis - Junction Temperature

specification for the product. The designer should specify any other goals that will influence the design, such as special optical and hardware requirements, like the selection of LED chips, drive current, etc. directly impacts thermal performance, and hence the mechanical design.

After the defining goals, in accordance with the optical and hardware requirements, choosing the type and number of LEDs and the drive current for the LED chips, the designer should start the mechanical design. Once an acceptable mechanical design is achieved this can be used for a first thermal analysis, and subsequent optimization study.

System Configuration

To design an effective cooling solution as part of the luminaire design, designers and analysts need to fully understand those aspects of the design that affect thermal performance, and the principle of thermal resistance. Three things affect the junction temperature of an LED chip: drive current, thermal path, and ambient temperature. In general, the higher the drive current, the greater the heat generated at the die. Heat must be moved away from the die in order to maintain expected light output, color, and lifetime

The inset in Figure 3 shows a 1D heat flow path from the LED junction down to the heatsink. The thermal resistance of the thermal grease or pad is one of the important parameters affecting the junction temperature. The designer can use the better thermal grease/pad that has a lower thermal resistance to help reduce the junction temperature. However, it should not be forgotten that a higher performance thermal grease/pad can increase the cost of your product, and so forms part of the cost optimization challenge when designing a luminaire.

To optimize the thermal design, the influence of the number of fins on the outer casing was investigated as a parametric study with 10, 15, 20, and 25 fins. The design with 15 fins was found to offer the best thermal performance.

A prototype was built, and FloEFD was found to have predicted temperatures on the casing to within a degree, and the junction temperature of the LEDs to within 2.8°C of experimental values.

Having successfully optimized the thermal design, it was necessary to complete an aerodynamic analysis on the luminaire as it is mounted on a 15m high pole. The specification for the test comes from TEDAS, the Turkish Electricity Distribution Company. At a wind speed of 57 m/s side on to the luminaire, the drag coefficient is 0.46, resulting in a drag force of 47.2N giving a bending moment based on the height of the pole as 0.71kNm. This is substantially less than the maximum 19.8kNm set in the specification. Front on to the flow, the drag coefficient is only 0.1, so the bending moment is correspondingly less.

In conclusion, Vestel's Ephesus street light design was analyzed and thermally optimized with FloEFD, fully meeting the thermal design criteria for the product. Wind forces on the pole-mounted luminaire were also simulated and the Vestel Ephesus M3 design was confirmed not to pose any safety risk due to aerodynamic loading.

References:

[1] "Thermal Management of White LEDs" Building Technologies Programme PNNL-SA-51901, February 2007.

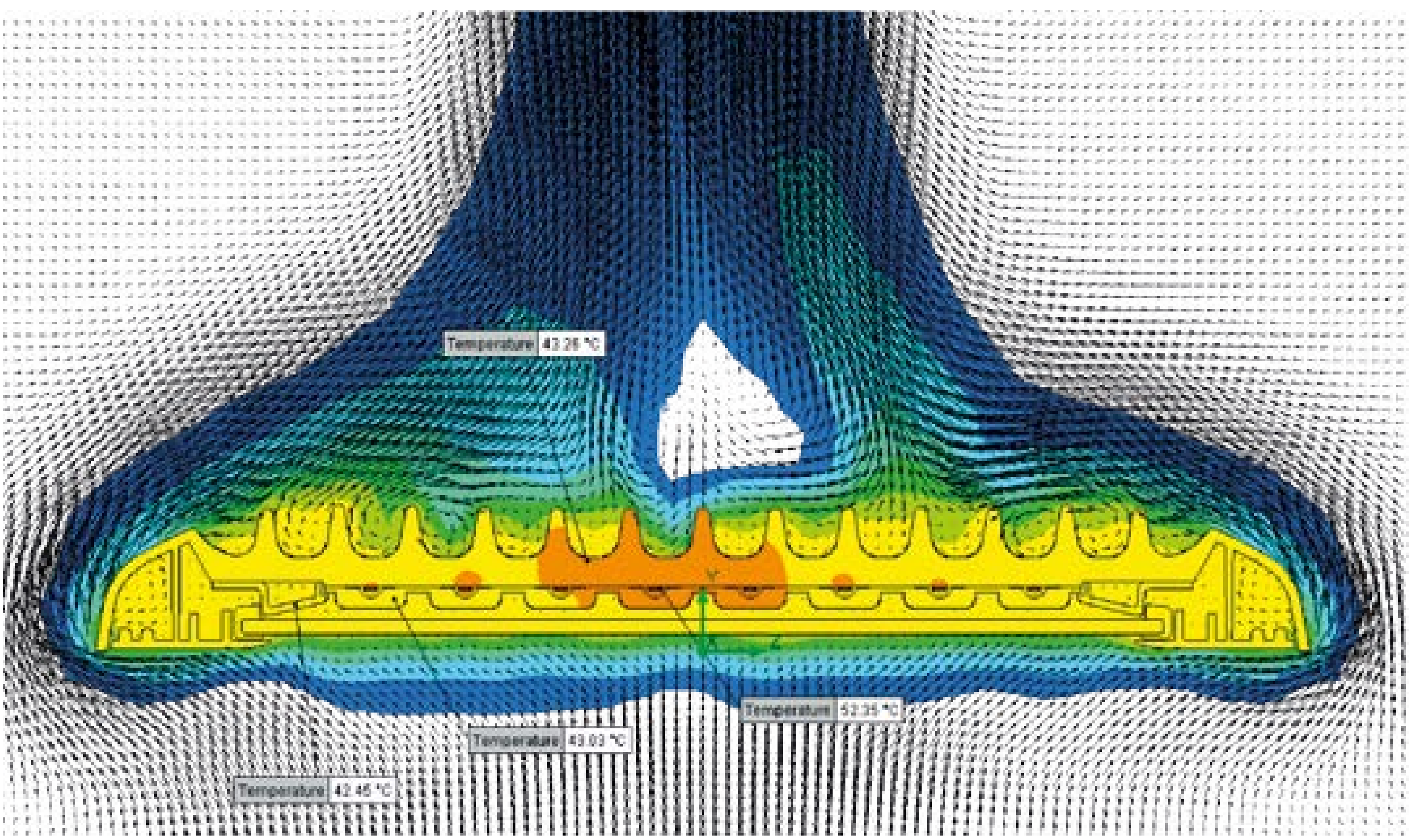

Figure 5. Top Surface Junction Temperature