Thermoplastic Heat sink for LED Lighting Systems

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Abstract— one of critical challenges in LED Lighting system design is the thermal management. The light output of the LED Lighting system is dependent on the Junction temperature. The design of heat sink plays a very vital role in the design. Conventional methods of heat sink manufacturing include materials such as aluminum, copper or combination of aluminum-copper being used. However considering the current trend of manufacturing process, the cost of metal heat sinks has increased. It curbs the design feasibility. In order to achieve a compromise between thermal management and manufacturing cost thermo plastic materials are introduced to replace the metallic heat sinks. This paper presents the design feasibility and thermal management of LED Lighting system with Thermoplastic Heat sinks.

Key words: Thermal Management, Conduction, Convection, Thermoplastic Materials

I. INTRODUCTION

Many thermally conductive com pound available in a variety of crystalline thermoplastic matrices can be used to improve thermal management along with design feasibility. The properties which justify the extensive use of metallic components as heat sinks are the stiffness, thermal and electrical conductivity, their excellent resistance to wear and tear .However metals tend to be heavy also. This is very serious disadvantage in many industrial cases.

The primary reason for replacement of metal heat sink is the design feasibility and system optimization. In LED Lighting system, the manufacturers tend to elevate the overall efficiency by reducing the total weight and cost of the various parts. The effective method of reducing the overall cost is by improving the production process. In case of metal, the post production works such as surface treatment, painting leads to increase in the production cost. In the competitive marketing

World, it is necessary to come out with products of different design.

Hence in order to overcome the serious outcomes of metal heat sinks, thermoplastic heat sink may be used. Thermal management is not a role often assigned to thermoplastics, since thermal conductivity is not an attribute of traditional thermoplastics. Yet thermal management – controlled thermal dynamics applied with the objective of cooling or heating a product, part, or component – generally depends on thermal conductivity.

However, with the creation of a novel thermally conductive additive for thermoplastics, a variety of design options is available for designers of products who need to draw heat away from, or into, critical functional components. With the addition of controllable thermodynamic properties, thermo- plastics offer yet another engineering arena in which they can supplant metals and other traditional materials.

II. THERMAL MANAGEMENT

Thermal management has become indispensable to the LED Lighting system. Due to its very low electro-optical conversion efficiency, most of the input power is converted to redundant heat. This phenomenon has a terrible effect on light output and the forward voltage of the LED at a specified current. In case of LED Lighting system about 70 % to 80% of the supplied electrical energy is converted to heat and about 15% to 20% is converted into visible light [1]. Hence, thermal management in LED devices is especially important for the performance and reliability as compared to conventional lighting system

A data published by a lighting company showed 30 different types of field failures from 5500 outdoor LED luminaries. The majority of failures about 52% where caused due to driver failures , the luminaries enclosure was responsible for 31% failures; LED packaging was responsible for 10% and the driver controls caused around 7% failures [2].

LED luminaire failures can be classified as disastrous failure and design defects. [3].Due to improper design like bad heat management, LED luminaire failure takes place. These failures can be detected during testing and can be rectified while designing the luminaire. This type of failure affects the long term reliability of the lighting devices. Light output from the luminaire is dependent on various sub-systems within the fixture.

III. HEAT TRANSFER MECHANISM

In general there are three modes of heat transfer such as conduction, convection and radiation. Conduction is the transfer of heat to lower temperature body from the body of high temperature. There is no displacement of molecules due to conduction. The conduction coefficient of heat transfer (K) is expressed as the transfer of the heat in watts per hour per square meter of the temperature difference.

Convection is the transfer of thermal energy from the surface to a fluid, where the fluid may be gas or liquid. The fluid circulation may be caused due to variations induced by thermal radiance in the fluid. Convection is also known as free conduction. The convection coefficient is expressed as the heat flow rate in watts per hour per square meter of the surface area pattern difference.

In LED lighting systems thermal conductivity between LED and heat sink is preferably by conduction and convection mechanisms. In this lighting system , the transfer of heat from the heat sink to surrounding atmosphere is through convection and the flow of thermal energy from the LED to the heat sink depends on the conduction mechanism. When the system is conduction limited, then metallic heat sinks are preferred. But if the system is convection limited, then thermoplastic materials can be used. As the thermal management in LED lighting system has both convention and conduction modes of heat flow, Thermoplastic heat sinks can be used.

IV. PROPOSED MODEL

This paper explains the new LED Lighting system with thermal conductive polymer based luminaire. Here instead of using metallic heat sink. Thermoplastic heat sinks are being employed. A new thermally conductive compound available in a variety of crystalline thermoplastic matrices which can be used to improve the material management in a variety of industrial and consumer applications. Replacing heavy metal shrouds, the new compounds are non-corrosive, can be processed from conventional thermoplastic equipment and have design freedom.

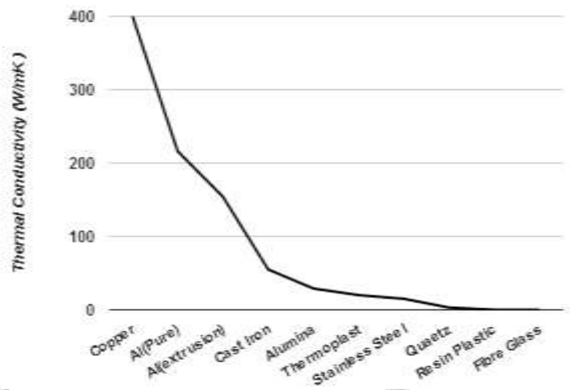

Fig. 1: Thermal Conductivities Of Various Materials.

Here the entire luminaire is made up of thermoplastic material hence the whole luminaire can act as the heat sink. Now a day's thermoplastic materials are available with high heat deflection temperature of about 195°C to 210°C. While replacing the metals with thermally conductive materials, it is important to understand the performance of the current materials as well as the application requirements.

The thermoplastic materials are insulators and in their unmodified state do not possess the needed thermal conductivity to provide thermal solutions. However, there is significant spread in the conductivity performance of the metals that are currently being used in the thermal management applications. In some applications metals may have more thermal conductivity than the application requires. Thus the fact to provide thermally conductive thermoplastic materials is to understand how much conductivity is needed.

V. IV IMPROVING THE THERMAL CONDUCTIVITY OF THE THERMOPLASTIC MATERIALS

The thermal conductivity of the base polymer ranges around 1.3 to 16 W/ m- K. However the thermal conductivity can be enhanced by using various kinds of fillers. In general the fillers are categorized into three types. They are

- Carbon Fillers: carbon fibres, carbon powder.
- Metallic Fillers: copper powder, steel, aluminium powder, aluminium flake.
- Ceramic Fillers: boron nitride, aluminium nitride, aluminium oxide.

In general the thermal conductivity of unfilled thermoplastics is 0.25 to 0.3 W/m-K.

But by using various fillers, the thermal conductivity can be improved around 200 to 500 times of the base component.

The metallic fillers will be electrically as well as thermally conductive, while the ceramic fillers posses only thermal conductivity. The Carbon Fiber Reinforced Plastics (CFRP) posses thermal conductivity ranging from 2.5 to 220 W/m-K and the coefficient of thermal expansion ranging from 1.7 x 10^{-6} to 23.6 x 10^{-6} /"K [4].

Aluminum nitride and boron nitride are the most commonly used fillers to the thermoplastic materials. The graphite fiber which is made from petroleum pitch have a conductivity values ranging from 500 - 1000 W/m-K [5]. Thus the required thermal conductivity and the other para-meters can be varied according to application by using the various kinds of fillers.

VI. BENEFITS OF METAL REPLACEMENT

The specific gravity of the thermo plastic heat sink is 1.5 to 2.3. The manufacturing cost of the thermo plastic heat sink is very low when compared to the metallic counter-part. In case of aluminum or copper heat sink, the manufacturing cost is very high, because they require more secondary production works such as polishing etc. The thermally conductive thermo plastic material shows comparable costs for comparable performance, if the entire thermal system is taken into account for example, aluminum with forming and machining cost, plus thermally coupling grease. Thus the fact is that the thermo plastic heat sink have low production cost when compared to the traditional metallic heat sinks.

Thermoplastic materials are recyclable and hence they are environmental friendly. Another merit with the thermoplastic heat sink is the design feasibility. In case of metallic heat sink there is a possibility of electromagnetic interference which limits its scope of application. Whereas in case of thermoplastic heat sink there is no such limitations.

VII. CONCLUSION

The main goal of this work is to develop a LED Lighting system with thermoplastic heat sink capable of effective thermal management and to have a flexible design during manufacturing process. Thus in a world with ever-increasing need for thermal management, the replacement of metallic heat sink with thermoplastic heat sink offer a wide range of flexibility in design, reduction in the manufacturing cost and light weight with high productivity.

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