# Unidirectional and Bidirectional Thermal Analysis of Magnesium based Aluminum Alloys

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**Abstract— Magnesium based aluminum alloys have been widely used in recent years as heat dissipating and lightweight structural materials in the manufacturing of automobiles, airplanes, and portable computers. Magnesium alloys have extremely low density (as low as 1738 kg ·m−3) and high rigidity, which makes them suitable for such applications. In this study, unidirectional and bidirectional thermal analysis of two different magnesium based aluminum alloys made by casting was investigated using Steady State Thermal module of Ansys Workbench 17.2. The heat transfer within the magnesium based aluminum alloys, form by 92% Aluminum + 8% Magnesium and 88%Aluminum + 12% Magnesium was studied for temperature 100 °C. The results indicate that the increase in magnesium percent in aluminum alloy results in high heat transfer material. The expose of magnesium based aluminum alloy's flat plate in bidirectional convection result in high heat transfer profile.**

**Index Terms— Heat Sink, Magnesium based Aluminum Alloys, Steady State Thermal Analysis**

## I. INTRODUCTION

Magnesium alloys have a low density, 1738 kg $\cdot m^{-3}$, and a high specific stiffness and are used as lightweight structural materials [1]. Their vibration and shock absorption properties are good, along with their excellent electrical, thermal conductivity, high temperature fatigue, and impact properties. As their densities are lower than that of aluminum (2698 kg $\cdot m^{-3}$), lightweight structures (parts) of popular vehicles, aircraft, transportation equipment, and general machinery are fabricated from magnesium alloys [2][3]. High thermal conductivity, low thermal expansion and low density are three important features in novel materials for high performance electronics, mobile applications and aerospace. [4] In recent years, devices such as mobile phones and portable laptops have parts made from magnesium alloys to reduce the weight, and as a result, manufacturing research and development in this area are actively ongoing [5]. AZ-series alloys are essentially alloys that include aluminum and zinc, with a magnesium base. AZ31, specifically, is an alloy of 3mass% Al and 1mass% Zn, whereas AZ61 is an alloy composed of 6mass% Al and 1mass% Zn. AZ91, with added Mn was developed and used for strengthening corrosion resistance [6]. Recently, notebooks require high thermal performance for higher speeds and increased heat dissipation. Such thermal performance is also essential for maintaining an enhanced cooling environment for lightweight parts in automobiles and personal computers. Information about the thermo physical properties of magnesium alloys such as the specific heat capacity and thermal conductivity are relatively scarce. [7] Thus, this article describes a thermal analysis of heat transfer of magnesium-based aluminum alloys (produced by casting) form by 92% Aluminum + 8% Magnesium and 88% Aluminum + 12% Magnesium for 100 °C. [8]

## II. PHYSICAL PROBLEM AND MATHEMATICAL MODELLING

Thermal analysis was done on 2m x 1m flat surface. Unidirectional thermal analysis include the heat transfer in single direction which is along the positive X axis. Isothermal boundary layer was established at X=0m for Y=1m. It was set at constant temperature of 100 °C. Corresponding opposite side of flat plate was set as convective boundary layer. The Biot number set for analysis was 5. Remaining two side was set as zero heat flux which means insulated surface. Fig. 1 shows the physical problem along with the mathematical modelling established in Ansys Workbench.

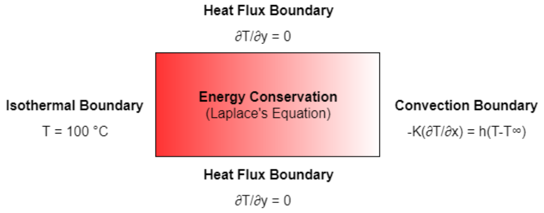

**Figure 1** Physical Definition and Mathematical Modelling of Unidirectional Heat Flow

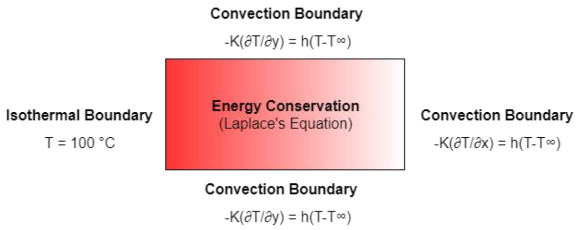

**Figure 2** Physical Definition and Mathematical Modelling of Bidirectional Heat Flow

Bidirectional thermal analysis include the heat transfer in two direction which is along the positive X axis and positive Y axis. Isothermal boundary layer was established at X=0m for Y=1m. It was set at constant temperature of 100 °C. All remaining side of flat plate was set as convective boundary layer. The Biot number set for analysis was 5. Fig. 2 shows the physical problem along with the mathematical modelling established in Ansys Workbench.

## III. GEOMETRY AND MESH DEFINITION

Geometry was define using Ansys Geometry. Fig. 3 shows the geometry prepared. The length and height of flat plate was set as 2m x 1m respectively. Fig. 4 shows mesh generation. The mesh was refine using face meshing and element size of 0.25m resulting in 32 numbers of rectangular elements.

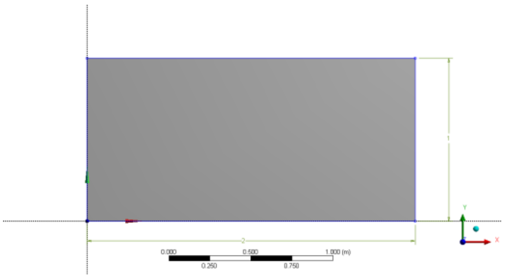

**Figure 3** Geometry Definition

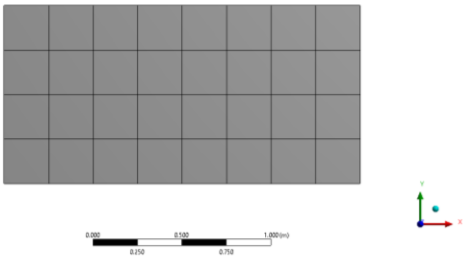

**Figure 4** Mesh Generation

## IV. NUMERICAL SOLUTION

The thermal analysis was done on two different magnesium based aluminum alloys which are Aluminum 92% + Magnesium 8% and Aluminum 88% + Magnesium 12%. Fig. 5 shows unidirectional heat transfer for Aluminum 92% + Magnesium 8%. It could be seen that the temperature drop within the flat plate from isothermal boundary layer to convection boundary layer was 5.718 °C. Similarly, Fig. 6 shows unidirectional heat transfer for Aluminum 88% + Magnesium 12%. It could be seen that the temperature drop within the flat plate from isothermal boundary layer to convection boundary layer was 7.008 °C.

Figure 7 shows bidirectional heat transfer for Aluminum 92% + Magnesium 8%. It could be seen that the temperature drop within the flat plate from isothermal boundary layer to convection boundary layer was 15.745 °C. Similarly, Fig. 8 shows bidirectional heat transfer for Aluminum 88% + Magnesium 12%. It could be seen that the temperature drop within the flat plate from isothermal boundary layer to convection boundary layer was 18.836 °C.

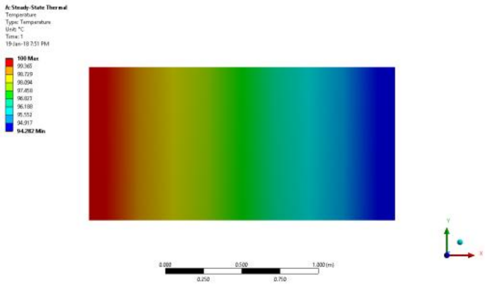

**Figure 5** Heat Transfer in Unidirectional for Al92%+Mn8%

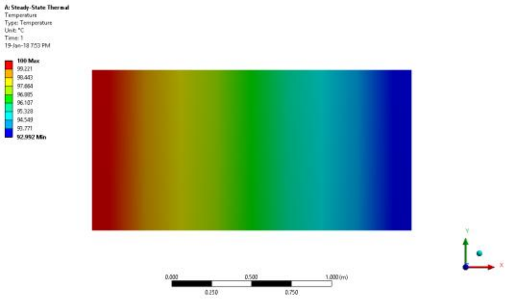

**Figure 6** Heat Transfer in Unidirectional for Al88%+Mn12%

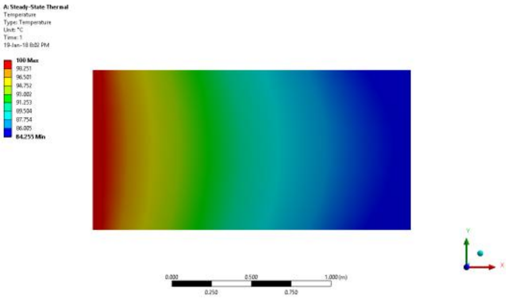

**Figure 7** Heat Transfer in Bidirectional for Al92%+Mn8%

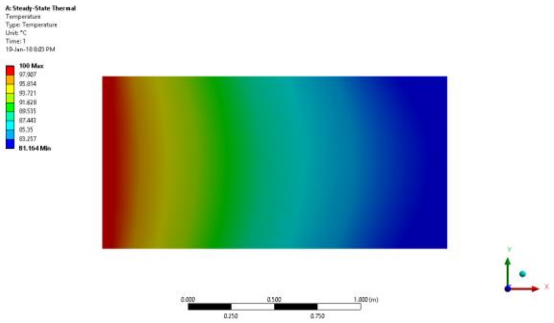

**Figure 8** Heat Transfer in Bidirectional for Al88%+Mn12%

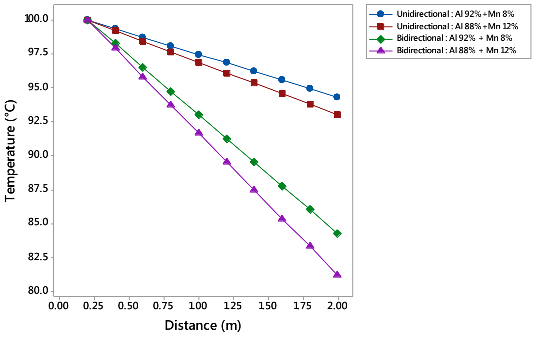

**Figure 9** Heat transfer comparison for Magnesium based Alluminum Alloys along the Length of Flat Plate (x = 2m)

Figure 9 shows the heat transfer within the flat plate (along length X=0 to X=2) for different magnesium based aluminum alloys in unidirectional and bidirectional heat flow. It could be seen that that Aluminum 92% + Magnesium 8% for unidirectional heat transfer gives very low heat transfer profile. Where else, Aluminum 88% + Magnesium 12% for unidirectional heat transfer produce much better heat transfer profile. Similar result was seen in bidirectional heat transfer where Aluminum 88% + Magnesium 12% produces much better heat transfer profile along the length of flat plate as compare to Aluminum 92% + Magnesium 8%. Bidirectional heat flow provide much better heat transfer from the flat plate to surrounding as compare to unidirectional heat flow. This plays important role when this alloy material used as heat sink. The heat sink should be provide bidirectional convection surface so to enhance heat transfer profile which also help to keep the heat sink temperature as low as possible.

## V. CONCLUSION

The increase in magnesium percent in aluminum alloy results in high heat transfer material. The expose of magnesium based aluminum alloy’s flat plate in bidirectional convection result in high heat transfer profile. Therefore, the design and location of magnesium based aluminum alloy used as heat sink for temperature 100 °C should be such that the fins where expose to bidirectional convectional fluid flow.

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