Heat Sink

Manufacturing Technologies

The most important issue in thermal management of electronics devices is to design cooling systems to maintain the device junction temperature below a set limit called maximum junction temperature. It has been proven that every 10ºC reduction in junction temperature will double the life expectancy of the device. In addition the performance of the device will increase with the reduction of the junction temperature. The most common and economical way to date for cooling devices has been air cooling using heat sinks.
The concept of using a heat sink is to transfer heat from the component level to a space where more air flow is available to dissipate the heat. Some of the parameters that are used to determine the selection of heat sink are amount of heat to be dissipated, maximum allowable junction temperature, thermal resistance of the device and natural or forced convention cooling and if forced the air flow in the system.

There are numerous ways to manufacturing heat sink. The most common ways of manufacturing of air-cooling heat sinks are as follows [1]

1. Extrusion
2. Stamping
3. Die Casting
4. Bonding
5. Folding
6. Forging
7. Skiving
8. Machining

Extrusion

Extrusion as a process by which a solid block is converted into a continuous length of uniform cross-section, by forcing it to flow under high pressure, thought a die orifice, which is so shaped, as to impart the required form to the product. Typically, billets of material are placed within a strong walled enclosure, and are caused to extrude through the die, under a powerful pressure exerted by a ram, actuated hydraulically or mechanically.[2]

Figure 1.- Typical Image of Extruded Heat Sink [3]

Extrusion is the most widely used method for heat sink manufacturing. Usually extrusions are 2 dimensional features and followed by machining process like adding features attach the component. A typical fin thickness is 0.60mm -

2mm, but there have been cases where it can go as low as 0.4mm. Capital investment and product cost are moderate, and secondary operations contribute approximately 15-20% of the part cost, and control product parameters such as tolerance, flatness, and surface finish. The flatness is an important factor for the performance of heat sink. The industry standard for flatness is 0.007in/in for heat sinks. In cases where this is not achieved directly from the extrusion, additional process like passing the heat sinks through time saves is carried out.

Stamping

Stamping is a process carried out using a power press, fitted with a metal stamping die, which transforms sheet metal into light weight, inexpensive, parts, capable of producing several thousand small parts per process stroke.

Actual obtainable volume depends on the size, geometry, and weight of the heat sinks, and the type of hardness of the material used. Heat sinks of any size could be manufactured by stamping, and can be commercially found up to 10cm in length. Thickness of the coil stock is a limiting factory, and maximum thickness is approximately 4mm. [4]

Figure 2.- Typical Image of Stamped Heat Sink [5]

Typical shapes for larger stamped heat sinks are U-Shapes with lances to form fins. Cost estimates for progressive and secondary dies are $8000 - $16000 and $1500 respectively. In certain application the heat sinks are fabricated with solder tips so that they can be attached directly to the board. Some disadvantages related to stamped heat sinks are sheared edges, die marks, and surface roughness.

Die-Casting

In the die-casting method molten metal is forced under pressure into metal dies or molds to produce accurately dimensioned parts. It is considered the fastest of all casting processes and is often employed where rapidity and economy in production are essential. The large initial investment required is offset by low part cost and minimal secondary operations, allowing economic manufacture for large production volumes. The thermal conductivity of cast heat sinks may be worsened by porosity caused by gases evolving during solidification. High tooling cost associated with die-casting results in large capital investment [6].

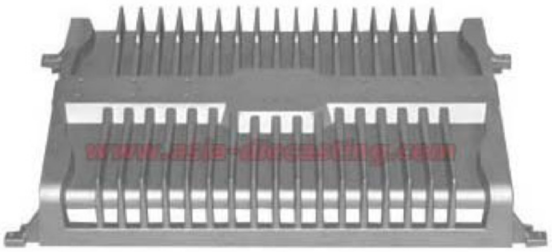

Figure 3.- Typical Image of Die-Casted Heat Sink [7]

To address the demand of high heat dissipation they one combine the stamping and die casting process to achieve extremely dense array of fins in a heat sink. A modified die-casting process involves the extension of basic die-casting principles, whereby the base of the heat sink is die-cast around a fixtured array of extremely thin stamped fins. The fins are separated by spacers, which prevent the die-cast material from flowing into the fin-to-fin spacing. While it may be possible to manufacture heat sinks of different materials, aluminum is the most commonly used material for this technique.

The absence of a so-called interface between the fins and the base eliminates the impact of an interface resistance. This process allows much higher aspect ratios while fulfilling requirements of small inter-fin spacing.

Some of the other manufacturing process that is used to achieve dense fins for high heat dissipation is as follows [8]:

Bonding

Bonded heat sinks are often built-up extrusions, typically manufactured by assembling extruded plates into slots on an extruded or machined heat sink base, and held in place by an interface, usually a two part thermosetting thermally conductive epoxy or a solder. The bonding agent does however represent a thermal barrier. These heat sinks are often costlier to manufacture, and the base typically requires special machining. Process limitations are usually related to the strength of the bonding agent and dimensional constraints for the slot in the heat sink base.

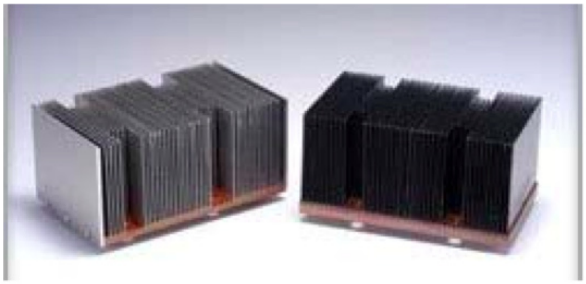

Figure 4.- Typical Image of a Bonded fin Heat Sink [9]

Hybrid heat sinks utilizing different materials for the fins and the base can be accommodated by this process. Bonded fin arrays are most commonly rectangular plate fin arrays.

Folding

Folded heat sinks are built-up sheet metal, manufactured by folding sheet metal into a serpentine fin array. The folded sheets of metal are attached to the base of the heat sink by soldering or brazing, which results in an additional thermal resistance at that interface. However, this contact resistance between the folded fins and the heat sink base is smaller than expected, due to the fact that the "bends" of folded fins are typically flattened while bonding or brazing, thus increasing the contact surface area.

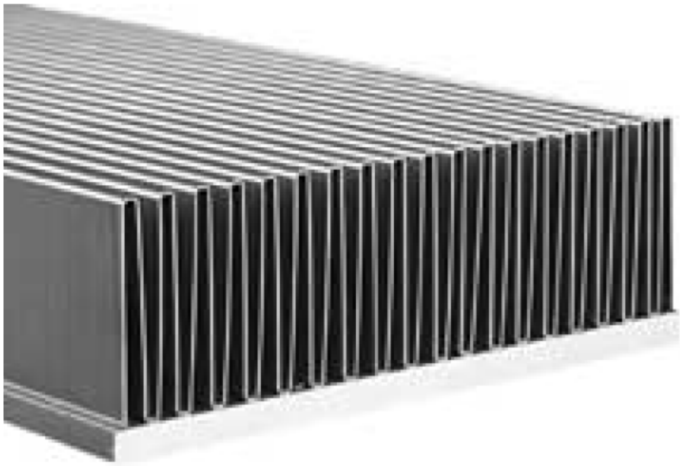

Figure 5.- Typical Image of Folded Heat Sink [10]

Difficulty in achieving smaller fin pitches required to construct dense arrays is a common issue. Similar to the bonding process, this manufacturing method allows flexibility in designing hybrid heat sinks made up of a combination of different materials.

Forging

In forged heat sink, the fin arrays are formed by forcing raw material into a molding die by a punch, which usually weighs about 500 tons (453,592.4 Kg). Common problems in forging are the choking of material in the molding die cavity, which could lead to fins of uneven height. Secondary processes may include cutting the fins, machining the base, polishing, or etching. While hot forging is inherently easier, cold forging results in denser and stronger fins.

Some of the drawback of this process is if secondary machining is required, it creates a lot of variation and burrs during the process. Since the base is curved, usually there is a tolerance for the number of fins to be +/- 2 fins.

Figure 6.- Typical Image of Forged Heat Sink [11]

Some of the attractive benefits of forging include high strength, superior surface finish, structural rigidity, close tolerance capabilities, continuity of shape, and high uniformity of material. Aluminum and magnesium alloys are easily forged, and an important economic advantage is a typically low rejection rate for the process.

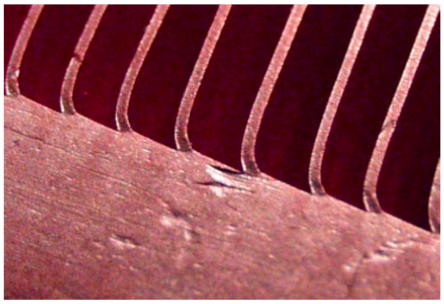

Figure 7.- Typical Image of Skived Heat Sink [12], [13]

Skiving

In the skiving process, fins are machined using special tooling, whereby precisely sliced layers from an extruded metal block are bent at the base of the slice to form slender curved fins. Since the fins and base is an integral unit, the interface resistance seen in folded and bonded heat sinks is not present. This process was originally developed to manufacture sparse natural convection arrays, but recent efforts have been focused towards achieving tighter fin spacing, necessary for forced convection cooling.

Aluminum 6063 is the preferred material on account of its superior machinability and strength, but copper arrays can also be made. The depth of cut determines the fin thickness and can be very low between 0.25 – 0.8mm, resulting in extremely thin fin structures, yielding light and competitive heat sink designs. The distance between fins can be shortened as much as 0.5mm and their height can reach 60mm thus the ratio of height thickness is around 150 times.

Machining

Heat sinks are machined out of a metal block by material removal to create the inter-fin spaces. Most commonly they are manufactured by gang saw cutting on a computer numerical control (CNC) machine. The gang saw consists of multiple saw cutters on an arbor with precise spacing, which depends on the heat sink geometry to be machined. In some cases machining is done using end mills. The advantage of this process is that there is minimum lead time. Solid bar stock is readily available and parts can be made very quickly as compared to other process which requires a lot of tooling lead time. Often, during machining, the fins are damaged and distorted, and require extensive secondary operations. Material is also consumed in an unproductive manner by the generation of scrap metal.

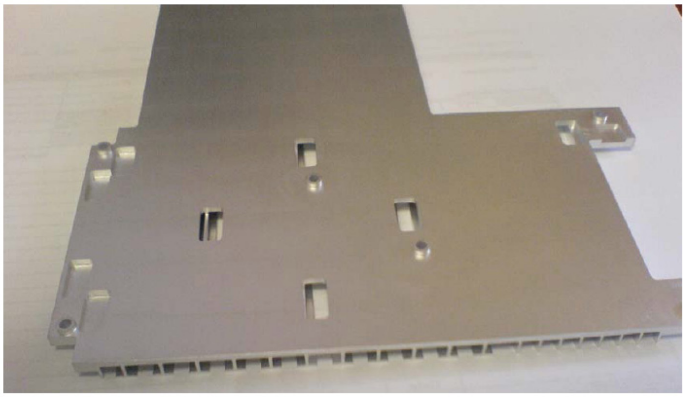

Figure 8.- Typical Image of Machined Heat Sink

Based on the type of application, the lead time, budged and thermal performance required different methods of manufacturing are used to produce heat sinks.

References:

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