DESIGN OF AN ELECTRONIC ENCLOSURE FOR DIE CASTING PRODUCTION

An exercise in the step-by-step design of an electrical or electronic enclosure as a die casting, applying recommended engineering principles and the 1999 NADCA Product Standards for optimum die casting results

Prepared by the Diecasting Development Council for OEM designers, specifiers and purchasers

Design of an Electrical or Electronic Enclosure

1. Introduction

This exercise addresses the design of an electronic enclosure, of the type that might be found in a wide variety of applications, such as communications equipment, automobiles, off-highway equipment, etc. It uses the 1999 *NADCA Product Specification Standards for Die Castings*. It is recommended that the latest copy of these Standards, which can be purchased by OEM specifiers from Chicago White Metal Casting at a special discount, be obtained for review.

The enclosure operates in an environment where atmospheric corrosion is minimal and galvanic corrosion is not a problem. It houses electronic components that are adhesive-bonded to the inside of the top wall (underside of the fins). The components transfer heat through the wall to the fins, where it is dissipated.

The enclosure is attached to a base by six (1/4 in.) 6 mm screws that pass through clearance holes in the flange. The enclosure operates in an environment that reaches 100°F (39°C). Service temperatures will be higher, depending on the cooling efficiency of the unit. Anticipated production rates are 500,000 per year.

2. Requirements

The purpose of this exercise is to verify what shapes can be made by die casting and to define design details.

The following functional requirements have been identified:

- Flatness of the surface at the base of the fins is critical to insure contact between it and the components attached to it.
- Flatness of the flange is critical, since it must fit against a mounting base and seal against an O ring.
- The mounting screws must maintain a prescribed force between the flange and the O ring against which it seats.

3. Issues to be Addressed

Two general categories of issues will be addressed in this exercise:

A. Alloy selection: general criteria for the Aluminum, Magnesium, Zinc and ZA groups.

B. Casting: identifying dimensions that can be computed from the standards and those that require input from the die caster.

3.1 Alloy Selection

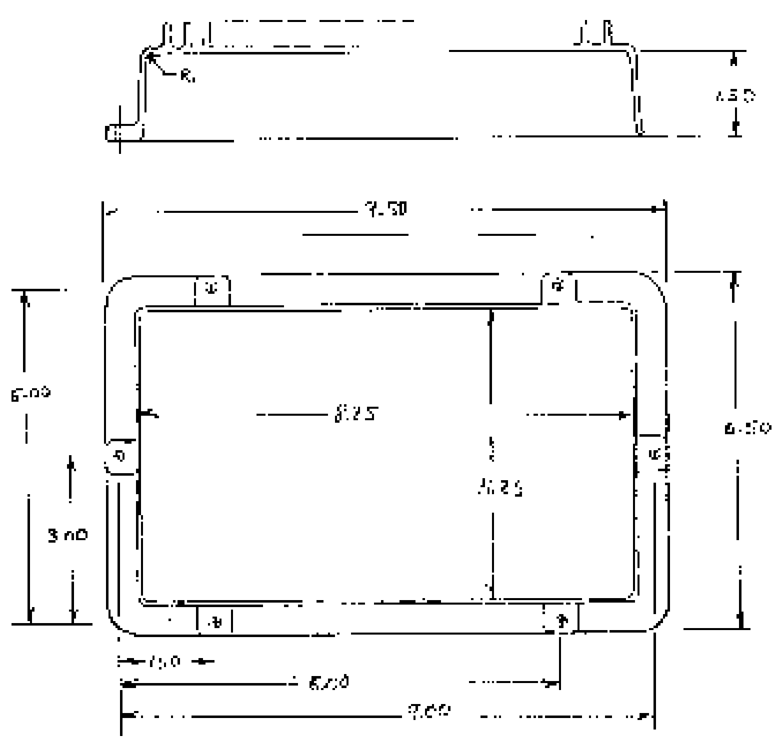
The first step in selecting an alloy is to look at the four groups. The operating temperatures apparently allow the use of aluminum, magnesium, zinc or ZA alloys.

(Refer to Figure 2.) This comparison shows that aluminum die casting alloys exhibit thermal conductivity that is significantly better than magnesium die casting alloys. 380 exhibits lower conductivity than zinc 3 and ZA-8, 360 is equivalent, and the other listed alloys are somewhat better. (Note that all of the listed die casting alloys are lower than aluminum extrusion alloys. However, extrusions do not lend themselves to the shape required for this application, and cannot be used.) Of the aluminum alloys, 380 offers the best combination of low cost, castability and availability, but it has relatively low thermal conductivity. Increased thermal conductivity can be realized by selecting alloys other than 380. If other aluminum alloys are considered, the following should be weighed:

- An alternate alloy will usually incur a higher purchase price.
- Non-critical walls may be somewhat thicker.
- 380 offers the widest availability, in that it is cast by virtually every aluminum die casting facility.
- If pressure tightness is a factor, it may be more difficult to achieve with some alternate aluminum alloys.

The balance of this study will be based on aluminum alloy 380. Magnesium may be considered when minimum weight is essential.

Fig. 1



The advantages of zinc alloy 3 and ZA-8 are summarized in the conclusion.

3.2 Casting Issues

The following casting issues have been identified. Some can be determined using the NADCA Product Standards while others are application-specific, and must be determined by consulting with the selected die caster. In this example,die caster consensus recommendations are cited.

1. The die caster recommends 0.075 in. (1.9 mm) minimum thickness for the side walls and flange.*
2. Side wall draft can be calculated from the NADCA Product Standards.
3. The allowable fin aspect ratio (ratio of fin height to thickness at the tip) depends on the location and orientation of the fins. In this case, the die caster recommends 4 to 5 as ideal, and 10 the maximum, with the caution that maximum aspect ratio will likely increase die maintenance and reduce die life.
4. The die caster recommends a minimum fin tip thickness of 0.060 in. (1.5 mm).
5. Draft on the fins can be calculated from the NADCA Standards.
6. The die caster recommends the minimum space between fins at the base to be 3 mm (0.125 in.) minimum; 0.250 in. (6 mm) is better for die life.
7. The radius at the tip of the fins can be calculated from the NADCA Standards.
8. The die caster recommends that the top wall (at the base of the fins) be at least as thick as the base of the fins.
9. Transition radii between features can be individually calculated from the NADCA Standards.
10. As-cast flatness tolerance for the mounting surface can be calculated from the NADCA Standards.
11. As-cast flatness for the mounting flange can be calculated from the NADCA Product Standards.
12. As-cast tolerance for the hole locations can be calculated from the NADCA Standards.
13. The required surface finish must be discussed with the die caster.

(Refer to Figure 2.) A thermal analysis based on aluminum 380 indicates that a fin with a tip thickness of 0.060 in. (1.5 mm) and a height of 0.300 in. (7.5 mm) is required. The aspect ratio is 5, and both dimensions comply with the die caster's recommendation.

Casting issues relating to fin dimensions can be seen in Figure 3. The die features between the fins must be thick enough to conduct away the heat of solidification. In this case, the recommended 0.250 in. (6.0 mm) fin spacing will be followed to promote maximum die life. Full radii will be used at the tip and base of the fins.

Fig. 2

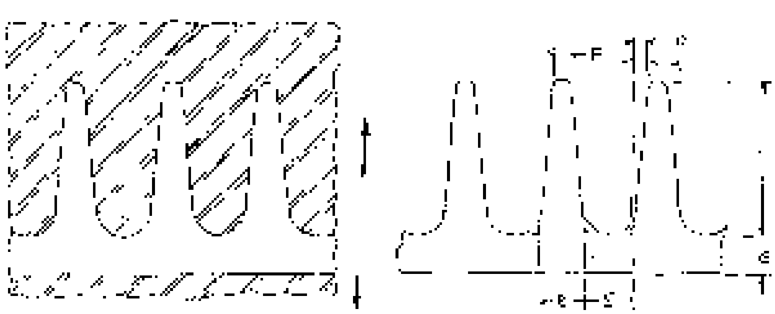
MATERIAL SELECTION FOR HEAT SINKS

Thermal Conductivity Comparison

	Thermal Conductivity			
Material	**W/m°C**	**%**	**%**	**Remarks***
1100 Aluminum	220	**100**	229	Extrusion
Aluminum Die Casting				
380	96	44	**100**	Lowest cost, best availability
360	113	51	117	Lower castability
413	121	55	126	Best castability
390	134	61	140	Poor castability
443	142	65	148	Lower castability
Zinc Die Casting				
Zamak 3	113	51	117	Best castability, best availability
ZA-8	115	52	120	Higher strength
Magnesium Die Casting				
AZ91D	72	33	75	Best availability, castability, thermal conductivity

*Remarks apply within alloy groups, but not across groups.

Fig. 3



4. Sample Calculations

Following are some sample calculations, based on the NADCA Standards:

A. Draft angle for fins. Use NADCA Standards, page 4-10. Since the fins are formed by cores, use data for inside wall.

C = 30

L = 0.300 (7.5)

Therefore D = 0.018 (0.46)

A = 3.48 use 3.5°

* The English-to-metric dimension conversions in this example are "hard" conversions, at 1"= 25.0 mm rather than 25.4 mm. Thus, the metric dimensions imply a slightly smaller casting than do the English.

B. Thickness of the top wall.

The die caster has specified that the minimum thickness (G) be equal to the fin width at the base (E). Fin base thickness is the tip thickness (F) plus the increase due to 3 1/2° draft per side over the length L = 0.30 (7.5 mm). The minimum base thickness is therefore:

E = F + (2 x D) which is 0.096 (2.4).

(Refer to Figure 1.)

C. Draft angle on the side walls of the enclosure. First, compute the draft for the inside surface, using the same draft data from the Standards as for the fins.

C = 30
L = 1.50 (38)
Therefore D = 0.041 (0.21)
A = 1.56° Use 1.5° minimum, preferably 2°.

Although the computed minimum draft on the outside surface is one-half as much, specify the same draft to maintain uniform wall thickness.

D. Flatness on inside surface, from the NADCA Standards, pages 4-12 (standard) and 4-13 (precision).

- Diagonal dimension of 8.25 in. x 5.25 in (210 mm x 135 mm) surface is 9.8 in. (250 mm).

  Standard: 0.008 + 7/1 x 0.003 = 0.029 in.
  0.2 + 175/25 x 0.08 = 0.76 mm

  Precision: 0.005 + 7/1 x 0.002 = 0.019 in.
  0.13+175/25 x 0.06 = 0.55 mm

The flatness of the surface is affected by the features connected to the wall (in this case the fins) and the amount of draft. Increased draft implies lower ejection forces and consequently less tendency for distortion during ejection.

E. Flatness of mounting flange, using the same standards as in calculation 3.

- Maximum dimension (diagonal) of 9.5 in. x 6.5 in. (240 mm x 165 mm) surface is 11.5 mm (290 in.).

  Standard: 0.008 + 9/1 x 0.003 = 0.035 in.
  0.2 + 225/25 x 0.08 = 0.92 mm

  Precision: 0.005 + 9/1 x 0.002 = 0.023 in.
  0.13 x 225/25 x 0.06 = 0.67 mm

If the die caster determines that the flange is susceptible to heat checking, he may opt to belt sand or grind the flange to remove the roughness and thus achieve the flatness.

F. Radius where side wall joins top wall (R1), using page 6-4 of the Standards: Where T2 > T1.

- Inside radius

  R1 = 2/3 (T1 + T2)
  = 2/3 (0.075 + 0.096)
  R1 = 0.114 in. Use 0.12 in.
  = 2.9 mm Use 3.0 mm

- Recommend that the outside radius equal the inside radius plus wall thickness to maintain uniform wall thickness.

G. Tolerance on mounting hole locations. The mounting holes can be cored from either side, depending on the die caster's choice of cover and ejector die locations. In either case, all of the holes are in one die member. Use the linear dimension tolerances on pages 4-4 and 4-5 of the standards. The longest location dimension, which will have the greatest tolerance, is 9.0 in. (225 mm).

Standard: ±(0.010 + 8 x 0.001) = ±0.018 in.
±(0.25 + 200/25 x 0.025) = ±0.45 mm

Precision: (0.002 + 8 x 0.001) = ±0.010 in.
±(0.05 + 200/25 x 0.025) = ±0.25 mm

The size and location tolerances of the tapped holes in the mating member should be checked and adjusted, if possible, to permit the as-cast tolerance calculated here.

5. Conclusion

In this type of application, magnesium alloy could have been considered if minimum weight was a prime requirement. Zinc or ZA-8 alloy would be an acceptable alternative to aluminum 380, depending on design factors which include the following:

- As the size of the enclosure becomes smaller, the economic advantages of zinc alloys increase.
- Zinc alloys allow a closer fin spacing and a greater aspect ratio than aluminum. This, combined with the higher thermal conductivity (versus 380), may generate higher cooling efficiency, reduced metal content or a lower fin height for improved packaging.
- Non-critical walls may be cast thinner in zinc alloys for additional reduction of metal content.

This exercise was not intended to achieve a finished design. It identified a number of casting issues, showed one possible design solution, and gave an idea of what to expect in discussing the application with a DDC die caster.

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