DESIGN OF A BRACKET FOR DIE CASTING PRODUCTION

An exercise in a step-by-step redesigning a part from a welded steel assembly to a die casting, applying recommended engineering principles and the 1999 NADCA Product Standards for optimum die casting results

DDO®

Prepared by the
Diecasting Development Council
of the North American
Die Casting Associaiton
for OEM designers, specifiers
and purchasers

Design of a Bracket

1. Introduction

This exercise involves the redesign of a part from a welded steel assembly to a die casting. 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 bracket shown in Figure 1 is a prototype, which was made as a welded assembly of 0.250 inch steel plate. It was used to verify the design concept, but is overdesigned for the application. The bracket is to be redesigned for quantity production as a die casting.

2. Requirements

The bracket operates in an environment where atmospheric corrosion is minimal and galvanic corrosion is not a problem. Estimated production is 200,000/year for five years. Maximum expected long-term operating temperature will not exceed 100°F (38°C). The bracket must resist deflection from loads as indicated by P_1 and P_2.

The essential features are:

A. A horizontal leg, which serves as a mounting surface, indicated as datum A.

B. A vertical leg, one surface of which must be held square to datum A as indicated.

C. A bushing hole with a nominal 0.5000 in. (12.50 mm) diameter, which receives a press fit bushing.*

D. A surface positioned a nominal 1.800 in. (45.0 mm) above datum surface A.

E. Three mounting holes in the horizontal leg.

F. A clearance envelope, which must be maintained to accommodate adjacent components.

G. Critical tolerances as shown.

The calculation of deflections is beyond the scope of this exercise, and no deflection data are given. The exercise will focus on the development of a thin wall rib reinforced structure with inherent stiffness in the required directions, which can be made at minimum cost. The design will be die castable, lend itself to FEA techniques and be easily

* 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.

Fig. 1

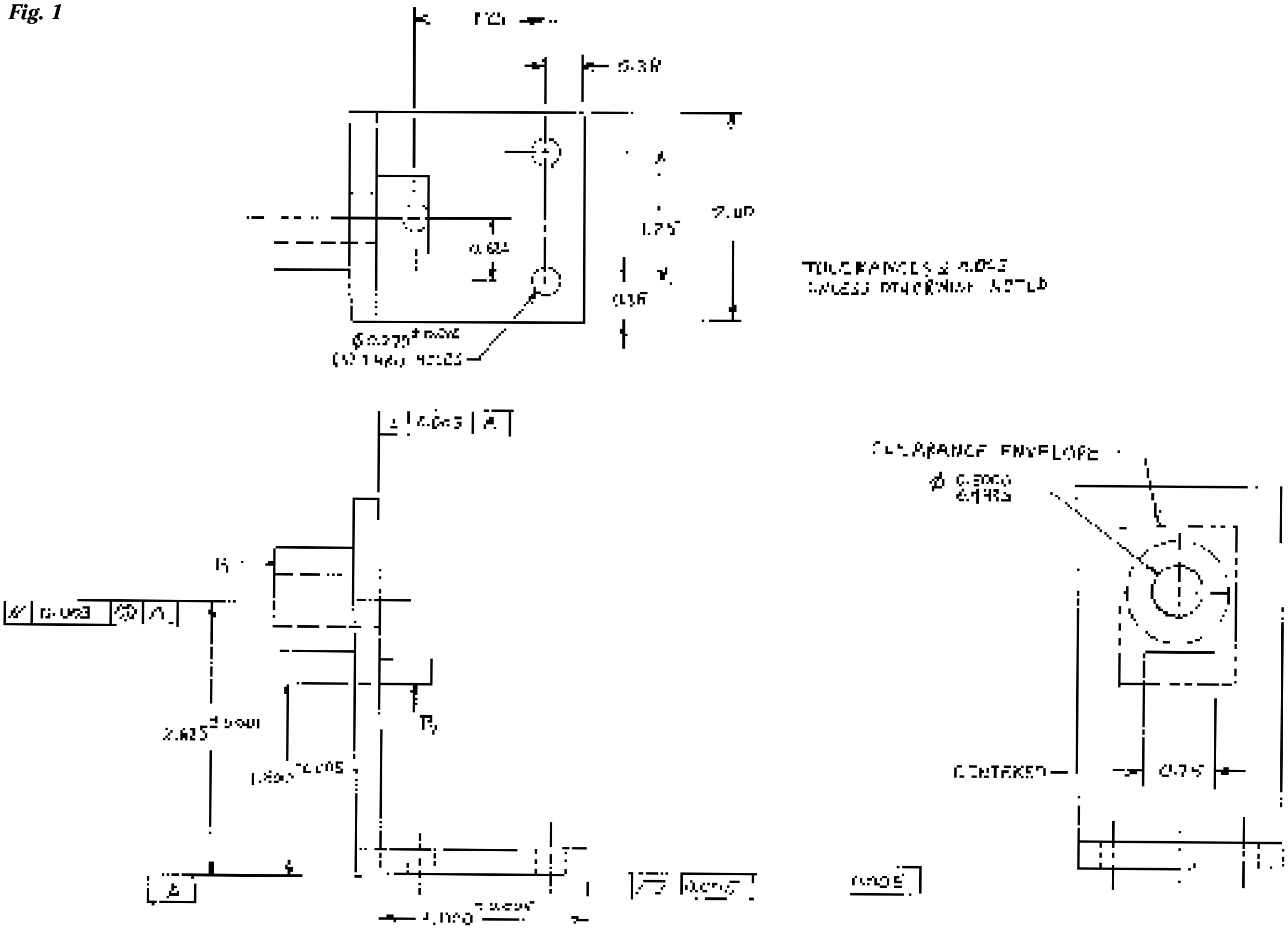


Fig. 2

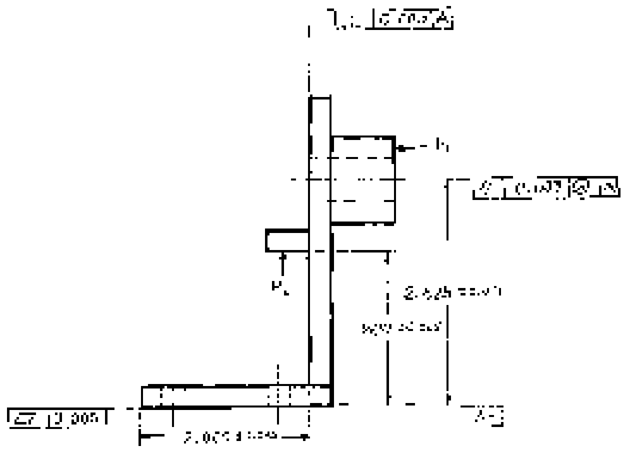
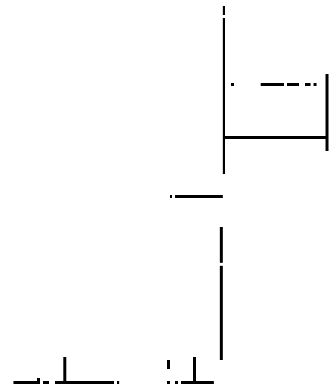


Fig. 3



modified to achieve the required performance.

3. Issues to be Addressed

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

A. Alloy selection: Consider general criteria for Aluminum, Magnesium, Zinc and ZA alloys in broad terms.

B. Shape: Develop a shape for the bracket that will permit die casting in the selected alloy using features that facilitate die casting and minimize the number of finish machining operations required.

C. Casting die: Identify the required die members.

D. Datums: Locate datum targets.

4. Application of Seminar Principles

This exercise employs the following concepts that were covered in the seminar:

A. Alloy selection.

B. Matching alloy properties to functional requirements.

C. Conceptual design—"function not form."

D. Use of uniform thin walls with rib reinforcements in place of thick sections.

E. "Tipping" the casting in the die to eliminate the need for core slides.

F. Datum target locations.

G. Cored versus punched holes.

5. Use of NADCA Standards

The NADCA standards will be used to establish a representative sampling of the following:

A. Draft angles on ribs, bosses and other surfaces.

B. Radii at junctures of features.

C. Tolerances on critical and non-critical features.

D. Flatness tolerances.

E. Datum target locations.

6. Alloy Selection

The first step in selecting an alloy is to look at the four groups, considering aluminum alloy 380, magnesium AZ91D, zinc 3 and ZA-8.

- The bracket is castable in all of the alloys.
- The requirement to retain residual tensile stresses in the hub may make ZA-8 preferable to zinc 3.
- The requirement for low deflection indicates that a high modulus of elasticity is desirable. Magnesium alloys exhibit the lowest MOE of the four groups, approximately 2/3 that of aluminum alloys; zinc 3 is equivalent to aluminum at low loads; and ZA-8 is 20% higher..
- Several dimensions require tolerances that somewhat exceed NADCA Precision specifications, and may need to be negotiated with the die caster. Zinc 3, ZA-8 and magnesium AZ91D may allow dimensions to be as-cast which would require machining in 380 aluminum.
- Aluminum will incur the highest die maintenance and replacement costs over the expected product life, zinc the least, and ZA-8 nearly the same as zinc.
- Answers to the foregoing must be determined by consulting qualified die casters.

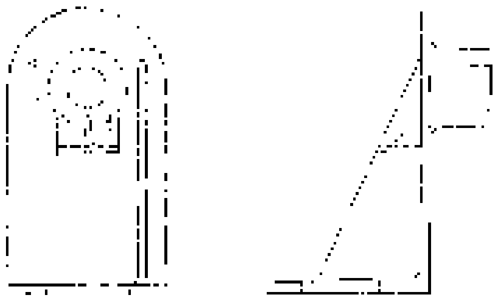
7. Developing the Design

A. Choose the view in which to work. The optimum view is the one that best:

- Shows the characteristic shape of the bracket
- Indicates the orientation of features to be cast.

  (Refer to Figure 2.) In this case, the optimum view is the lower left, which shows

Fig. 4



the characteristic "L" shape and the casting directions of holes and bosses.

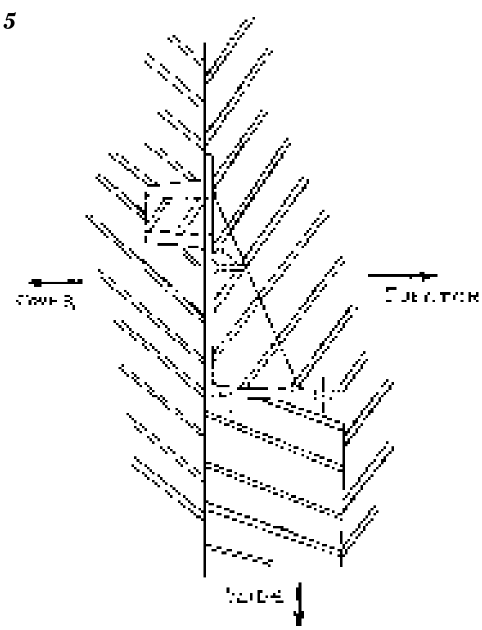
B. Select the features that have a reasonable probability of being achieved as-cast and those that will definitely require machining.

- The size and location tolerances on the three mounting holes appear to be castable.
- The size and location tolerances on surface at P_2 appear to be castable.
- The flatness tolerances may be castable.
- The squareness tolerance may be castable.
- The size and location tolerances on the bushing bore must be machined, probably by boring, in order to maintain the size, location and parallel tolerances.

C. Identify and sketch the critical functional surfaces. (Refer to Figure 3.) There are five functional surfaces:

- Bottom mounting surface
- Rear surface of vertical leg

Fig. 5



- Bottom surface at P_2
- Inside and face of bushing boss
- Inside surface of three mounting holes

D. Complete the design in a die castable form. The following will be assumed. When NADCA standards are used, aluminum data will be cited first with data for alternate alloys following.(Refer to Figure 3.)

- 0.120 in. (3.0 mm) wall thicknesses on horizontal and vertical legs for aluminum and zinc, 0.140 in. (3.5 mm) for magnesium and 0.115 in. (2.9 mm) for ZA-8. (The varying thicknesses develop equal bending stiffness, given the variations in MOE.)
- 0.080 in. (2.0 mm) wall thickness on ribs for aluminum and zinc, 0.095 in. (2.4) mm) for magnesium and 0.075 in. (1.9 mm) for ZA-8.
- O.D. of bushing hub a minimum of two times I.D.
- Minimum draft angles per NADCA standards
- Blend radii per NADCA standards

(Refer to Figure 4)

This is one possible solution. The main difference between it and the prototype is the use of thinner walls and reinforcing ribs. Note that they are placed just outside the clearance envelope, which is as close as possible to the hub where the load P_2 is applied. The ribs are a likely location for elector pins. They should be placed far enough from the clearance envelope to allow for ejector pin pads. The ribs extend up the vertical surface to the top of the hub, and across the bottom leg to the vicinity of the rear mounting holes. This arrangement involves the ribs in distribution of the load from the surface on which it is received to the surface on which it is transmitted to the next member.

The surface at P_2 is also reinforced with ribs. One, two or three may be satisfactory. In this case, three are employed.

The top of the prototype bracket was square because that was the simplest way to cut off the required stock. The top of the die cast bracket is rounded to conserve metal.

E. Show the design in the die casting die.
The bracket can be cast in either of two die arrangements.

1. (Refer to Figure 5.) This arrangement establishes the parting line on the left edge of the vertical leg of the bracket. The cover die is to the left, ejector die to the right. A core slide forms the bottom surface (A datum) and holes.

The hole diameters and locating dimensions are in the core slide, so the tolerances are basic. The required hole diameter tolerance is ±0.010 (±0.25 mm) and the location tolerance is ±0.005 (±0.13 mm). Referring to page 4-4 of the NADCA Product Standards:

- The standard linear tolerance for the hole diameter is ±0.010 in. (±0.25 mm), which is specified.
- Standard tolerance on the locating dimensions, which are between 1.00 in. (25 mm) and 2.00 in. (50 mm), is:

  ±0.010 in. for the first inch
  (±0.0.25 mm for the first 25 mm)

  ±0.001 in. for the second inch
  (±0.025 mm for the second 25 mm)

  Total ±0.011 in. (±0.28 mm), which is greater than specified.

Referring to NADCA Product Standards page 4-5, the precision tolerance is:

±0.002 in. for the first inch
(±0.050 mm for the first 25 mm)

±0.001 in. for the second inch
(±0.025 mm for the second 25 mm)

Total ±0.003 in. (±0.08 mm).

Therefore, the hole diameters are within standard tolerance, and locating dimensions will require precision tolerances.

The bottom surface A has a flatness requirement of 0.005 in. (0.13 mm). Referring to NADCA, page 4-12:

- The diagonal of the surface is about 3.0 in. (75 mm).
- The standard flatness tolerance is 0.008 in. (0.2 mm).

Referring to NADCA, page 4-13:

- The precision flatness tolerance is 0.005 in. (0.13 mm).

The flatness tolerance is within the precision standard.

The vertical leg has a squareness tolerance, which is not covered by the standards, and must be negotiated with the die caster. However, the squareness tolerance implies an equal flatness tolerance. The major dimension is approximately 3.0 in. (75 mm), so that the expected flatness tolerance is 0.005 in. (0.13 mm), the same as for the base.

The 1.80 in. (45 mm) location dimension goes from the ejector die to the core slide. It will require an additional tolerance, computed from pages 4-8 and 4-9.

- The projected area of the die casting is approximately 4.5 square inches, so the "up to 10 square inch" (64.5 cm²) data apply.

For standard tolerances, the basic tolerance is (NADCA page 4-4):

±0.010 in. for the first inch
(±0.25 mm for the first 25 mm)

+0.001 in. for the second inch
(±0.025 mm for the second 25 mm)

Total ±0.011 in (±0.275 mm).

The additional "cross-die" tolerance (NADCA page 4-8) is:

+0.008 in.
(+0.006 for zinc and ZA-8))

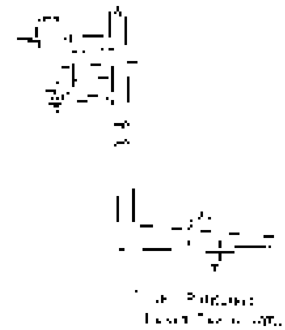


Fig. 6

The total tolerance is +0.019/-0.011 in. (+0.48/-0.28 mm) which exceeds the allowable ±0.005 in. (±0.13 mm).

For precision tolerances, the basic tolerance is (NADCA page 4-5):

±0.002 for the first inch
(±0.05 mm for the first 25 mm)

±0.001 for the second inch
(±0.025 mm for the second 25 mm)

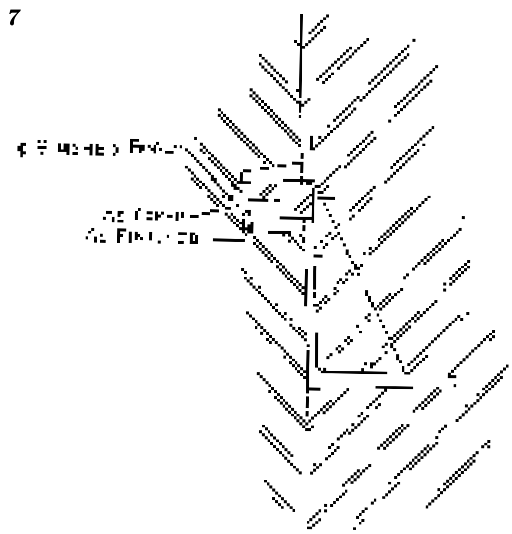
Total ±0.003 in. (±0.075 mm)

The additional "cross-die" tolerance is (NADCA page 4-9):

+0.006 in. (0.005 for zinc and ZA-8)
(+0.152 mm)

The total tolerance is +0.009/-0.003 in. (+0.008/-0.003 mm), which is slightly tighter than precision tolerance. The die caster must be consulted.

Fig. 7



This arrangement raises other questions.

- There is no draft for the underside of the feature at P_2. This may be castable by using 0.005 in. (0.13 mm) of the allowable tolerance as draft, and the remainder as casting tolerance.
- Datum targets are difficult to locate. The optimum is for all six to be in the ejector die. The best apparent arrangement is to put the three A targets on the vertical

surface, the two B targets on the side of one of the reinforcing ribs, and the C target on the bottom of the feature at P_2. The B and C targets are on surfaces that have draft and are not perpendicular to the surface with the A targets.

- Squareness of the vertical and horizontal legs is questionable because the vertical surface is in the ejector die and the horizontal surface in the cover die. The die caster must be consulted to see if machining operations are required.

2. (Refer to Figure 6.) The second arrangement tips the casting in the die so that the bottom surface can be cast in the ejector die and the core slide eliminated. The amount of tip is exaggerated here. The amount of tip corresponds to the amount of draft required on the bottom surface. Referring to NADCA page 4-10 for standard minimum draft:

- using outside wall (C = 60)
- L = 2.0 in. (50 mm)
- The draft dimension D is 0.236 in. (6.0 mm)

The calculated angle is 0.67°. 1° will be used.

(Refer to Figure 7.) With this casting arrangement, the core slide is eliminated. The relationship between the casting and die members is developed as follows:

- Keep the parting line in the same location as in A.
- Rotate the bracket counterclockwise in the die to allow the "A" datum surface to be ejected without requiring the core slide.
- Increase draft as required on other surfaces to permit ejection of the rotated casting:

  Top surface of the horizontal leg

  Bottom of the outside diameter of the bushing hub.
- Although the top surface of the bushing hub requires less draft than the bottom, the most practical design uses the draft indicated on the bottom for entire hub.
- The 0.5000/04995 inside diameter of the bushing hub is cored undersize and off angle. It will be cleaned up by a boring operation, as in option A.
- Holes in the base will be either drilled or punched.

This approach offers the following advantages:

- The core slide is eliminated, reducing die cost with other possible secondary cost reductions.
- The two surfaces with flatness and squareness tolerances, and surface at P_2 are all in the ejector half.
- The surface at P_2 now has a draft angle, the same as the bottom surface (A datum).
- The 1.80 locating dimension is now completely within the ejector die, and within precision casting tolerance of ±0.003 in. (±0.08 mm).
- The three A datum targets can be located on the back surface of the vertical leg, the two B targets on the bottom side of the horizontal leg, and the one C target either on the side of a main rib or on the side of the feature at P_2.

It offers one disadvantage, in that the holes in surface A will require a separate drilling or punching operation.

8. Conclusion

This exercise was not intended to achieve a finished design. It raised a number of design issues, showed two casting options and gave an idea of what to expect in discussing the application with qualified die casters.

The requirement for the press-fit bushing should be evaluated. It may be possible to use the bearing capability of ZA-8 or use 390 aluminum instead of 380 to eliminate the bushing and run on the finished surface. If these alloys do not meet the requirements, ZA-12 and ZA-27, which have superior bearing properties but require cold-chamber casting, should be investigated.

DDC®
DIECASTING DEVELOPMENT COUNCIL
OF THE NORTH AMERICAN DIE CASTING ASSOCIATION

9701 W. HIggins Rd., Suite 855
Rosemont, IL 60018
Phone 847-292-3625
Fax 847-292-3613