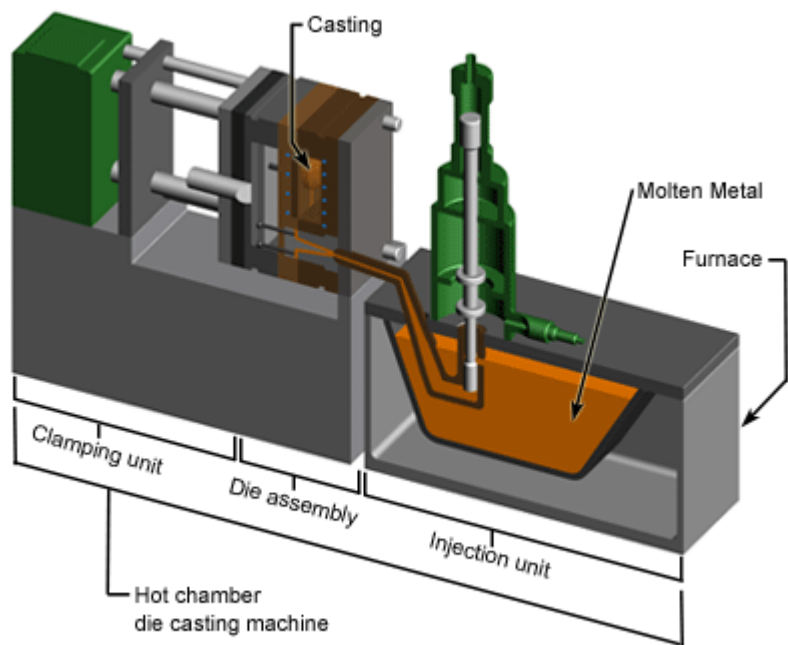# Introduction Of High Pressure Die-Casting

And

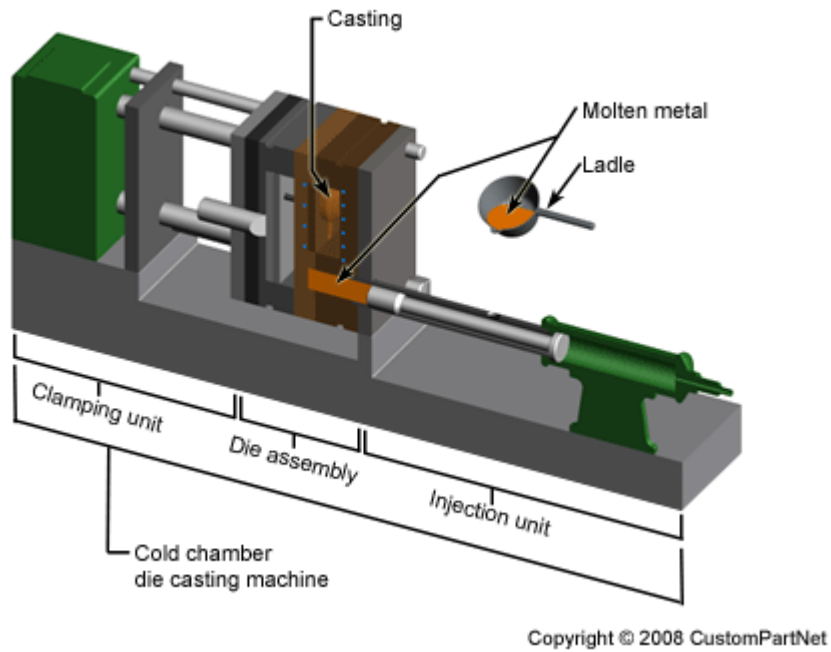# Common Defects In Die-Casting

Collected By

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Islamic Azad Univercity Of Saveh

Die casting is a manufacturing process that can produce geometrically complex metal parts through the use of reusable molds, called dies. The die casting process involves the use of a furnace, metal, die casting machine, and die. The metal, typically a non-ferrous alloy such as aluminum or zinc, is melted in the furnace and then injected into the dies in the die casting machine. There are two main types of die casting machines - hot chamber machines (used for alloys with low melting temperatures, such as zinc) and cold chamber machines (used for alloys with high melting temperatures, such as aluminum). The differences between these machines will be detailed in the sections on equipment and tooling. However, in both machines, after the molten metal is injected into the dies, it rapidly cools and solidifies into the final part, called the casting. The steps in this process are described in greater detail in the next section.

Die casting hot chamber machine overview

Casting

Molten metal

Ladle

Clamping unit

Die assembly

Injection unit

Cold chamber
die casting machine

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Die casting cold chamber machine overview

The castings that are created in this process can vary greatly in size and weight, ranging from a couple ounces to 100 pounds. One common application of die cast parts are housings - thin-walled enclosures, often requiring many ribs and bosses on the interior. Metal housings for a variety of appliances and equipment are often die cast. Several automobile components are also manufactured using die casting, including pistons, cylinder heads, and engine blocks. Other common die cast parts include propellers, gears, bushings, pumps, and valves.

Capabilities

	Typical	Feasible
Shapes:	Thin-walled: Complex Solid: Cylindrical Solid: Cubic Solid: Complex	Flat Thin-walled: Cylindrical Thin-walled: Cubic
Part size:	Weight: 0.5 oz - 500 lb	
Materials:	Metals Aluminum Lead Magnesium Tin Zinc	Copper
Surface finish - Ra:	32 - 63 µin.	16 - 125 µin.
Tolerance:	± 0.015 in.	± 0.0005 in.
Max wall thickness:	0.05 - 0.5 in.	0.015 - 1.5 in.
Quantity:	10000 - 1000000	1000 - 1000000
Lead time:	Months	Weeks
Advantages:	Can produce large parts Can form complex shapes High strength parts Very good surface finish and accuracy High production rate Low labor cost Scrap can be recycled	
Disadvantages:	Trimming is required High tooling and equipment cost Limited die life Long lead time	
Applications:	Engine components, pump components, appliance housing	

Process Cycle

The process cycle for die casting consists of five main stages, which are explained below. The total cycle time is very short, typically between 2 seconds and 1 minute.

1. Clamping

   - The first step is the preparation and clamping of the two halves of the die. Each die half is first cleaned from the previous injection and then lubricated to facilitate the ejection of the next part. The lubrication time increases with part size, as well as the number of cavities and side-cores. Also, lubrication may not be required after each cycle, but after 2 or 3 cycles, depending upon the material. After lubrication, the two die halves, which are attached inside the die casting machine, are closed and securely clamped together. Sufficient force must be applied to the die to keep it securely closed while the metal is injected. The time required to close and clamp the die is dependent upon the machine - larger machines (those with greater clamping forces) will require more time. This time can be estimated from the dry cycle time of the machine.

2. Injection

   - The molten metal, which is maintained at a set temperature in the furnace, is next transferred into a chamber where it can be injected into the die. The method of transferring the molten metal is dependent upon the type of die casting machine, whether a hot chamber or cold chamber machine is being used. The difference in this equipment will be detailed in the next section. Once transferred, the molten metal is injected at high pressures into the die. Typical injection pressure ranges from 1,000 to 20,000 psi. This pressure holds the molten metal in the dies during solidification. The amount of metal that is injected into the die is referred to as the shot. The injection time is the time required for the molten metal to fill all of the channels and cavities in the die. This time is very short, typically less than 0.1 seconds, in order to prevent early solidification of any one part of the metal. The proper injection time can be determined by the thermodynamic properties of the material, as well as the wall thickness of the casting. A greater wall thickness will require a longer injection time. In the case where a cold chamber die casting machine is being used, the injection time must also include the time to manually ladle the molten metal into the shot chamber.

3. Cooling

- The molten metal that is injected into the die will begin to cool and solidify once it enters the die cavity. When the entire cavity is filled and the molten metal solidifies, the final shape of the casting is formed. The die can not be opened until the cooling time has elapsed and the casting is solidified. The cooling time can be estimated from several thermodynamic properties of the metal, the maximum wall thickness of the casting, and the complexity of the die. A greater wall thickness will require a longer cooling time. The geometric complexity of the die also requires a longer cooling time because the additional resistance to the flow of heat.

4. Ejection

- After the predetermined cooling time has passed, the die halves can be opened and an ejection mechanism can push the casting out of the die cavity. The time to open the die can be estimated from the dry cycle time of the machine and the ejection time is determined by the size of the casting's envelope and should include time for the casting to fall free of the die. The ejection mechanism must apply some force to eject the part because during cooling the part shrinks and adheres to the die. Once the casting is ejected, the die can be clamped shut for the next injection.

5. Trimming

- During cooling, the material in the channels of the die will solidify attached to the casting. This excess material, along with any flash that has occurred, must be trimmed from the casting either manually via cutting or sawing, or using a trimming press. The time required to trim the excess material can be estimated from the size of the casting's envelope. The scrap material that results from this trimming is either discarded or can be reused in the die casting process. Recycled material may need to be reconditioned to the proper chemical composition before it can be combined with non-recycled metal and reused in the die casting process.

Cast Part

Flash

Part A

Runner

Sprue

Final Part

Part B
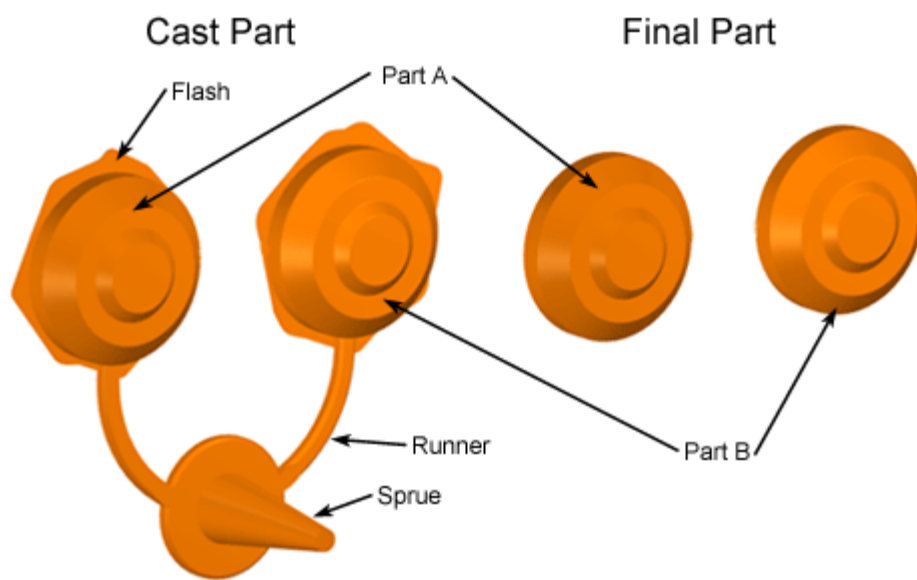
Die cast part

Equipment

The two types of die casting machines are a hot chamber machine and cold chamber machine.

- ## Hot chamber die casting machine

  - Hot chamber machines are used for alloys with low melting temperatures, such as zinc, tin, and lead. The temperatures required to melt other alloys would damage the pump, which is in direct contact with the molten metal. The metal is contained in an open holding pot which is placed into a furnace, where it is melted to the necessary temperature. The molten metal then flows into a shot chamber through an inlet and a plunger, powered by hydraulic pressure, forces the molten metal through a gooseneck channel and into the die. Typical injection pressures for a hot chamber die casting machine are between 1000 and 5000 psi. After the molten metal has been injected into the die cavity, the plunger remains down, holding the pressure while the casting solidifies. After solidification, the hydraulic system retracts the plunger and the part can be ejected by the clamping unit. Prior to the injection of the molten metal, this unit closes and clamps the two halves of the die. When the die is attached to the die casting machine, each half is fixed to a large plate, called a platen. The front half of the die, called the cover die, is mounted to a stationary platen and aligns with the gooseneck channel. The rear half of the die, called the ejector die, is mounted to a movable platen, which slides along the tie bars. The hydraulically powered clamping unit actuates clamping bars that push this platen towards the cover die and exert enough pressure to keep it closed while the molten metal is injected. Following the solidification of the metal inside the die cavity, the clamping unit releases the die halves and simultaneously causes the ejection system to push the casting out of the open cavity. The die can then be closed for the next injection.
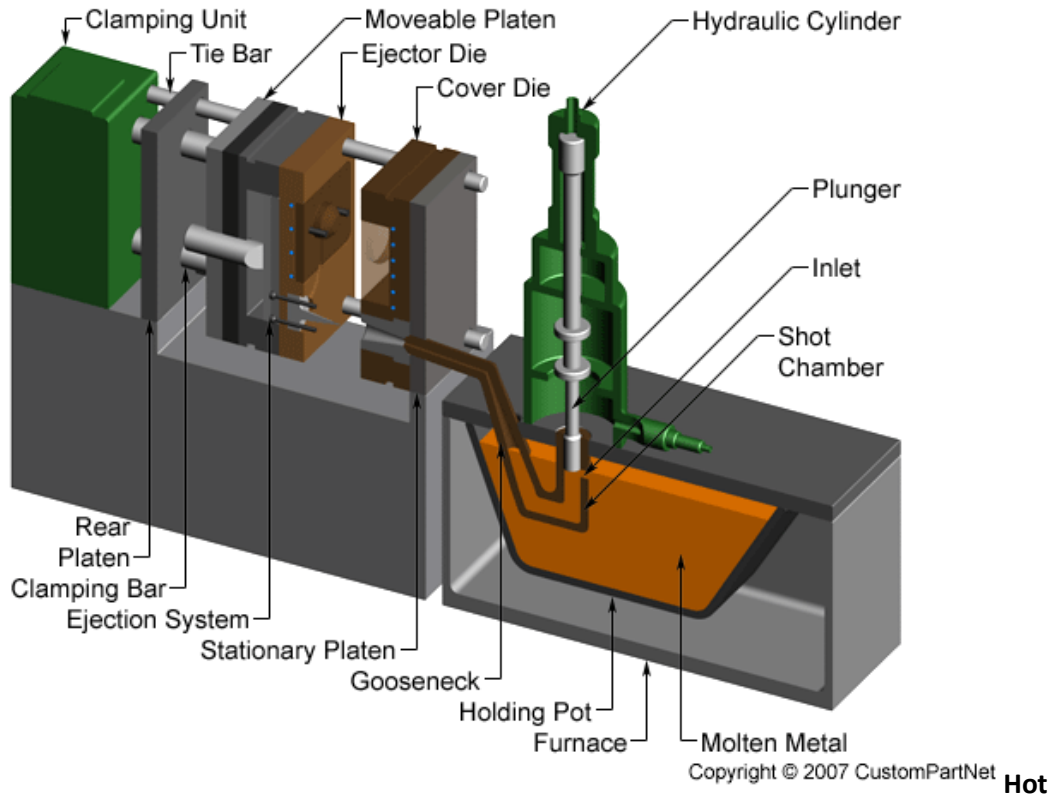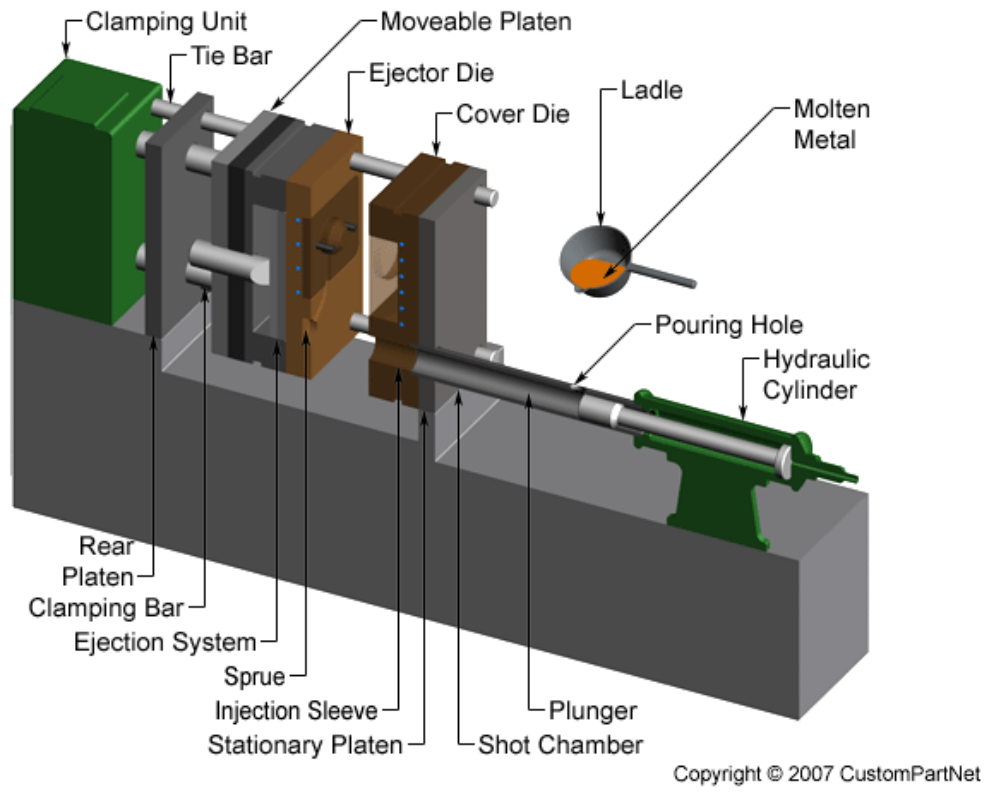
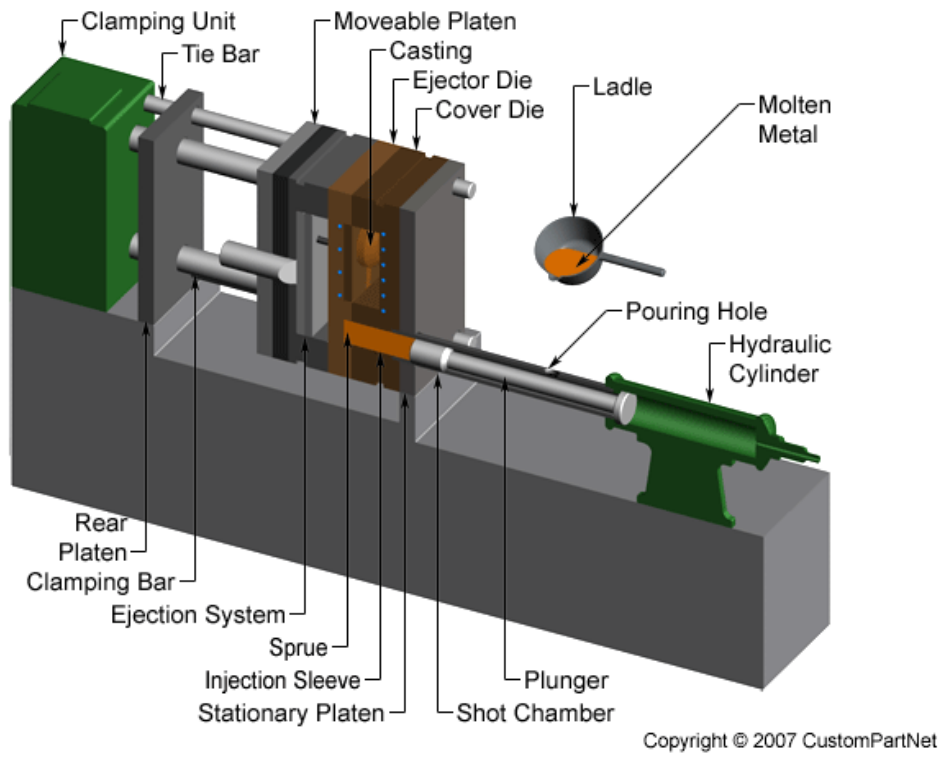**Hot chamber die casting machine – Opened**
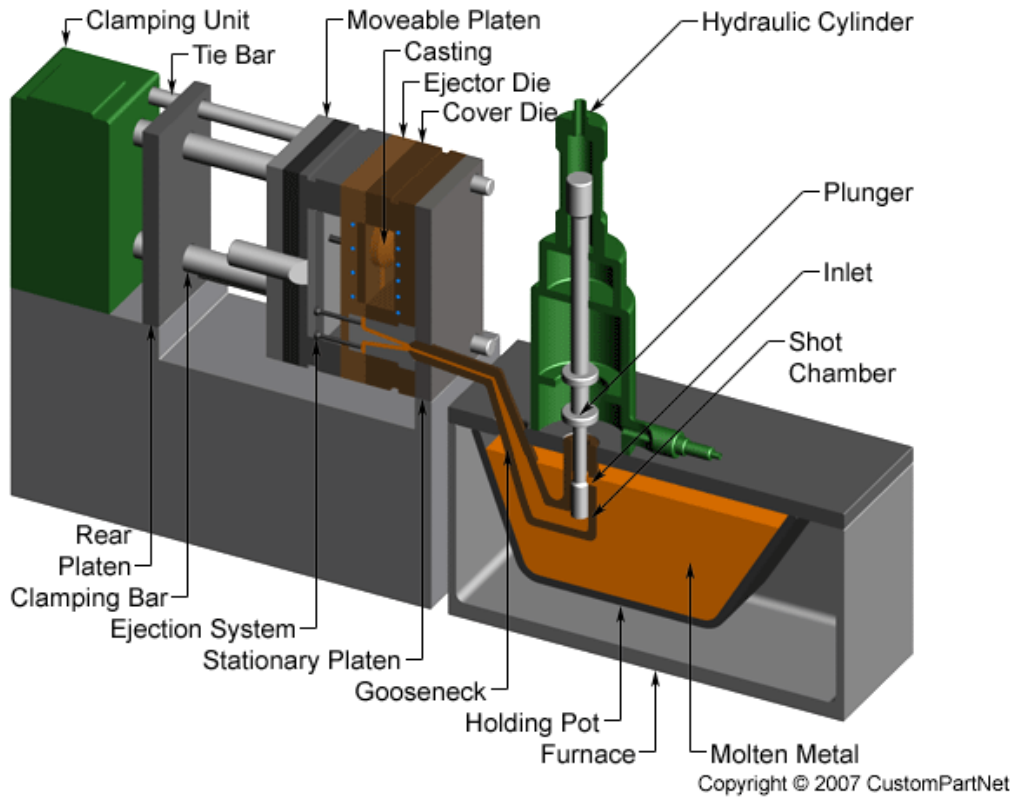
Hot chamber die casting machine – Closed

Cold chamber die casting machine

- Cold chamber machines are used for alloys with high melting temperatures that can not be cast in hot chamber machines because they would damage the pumping system. Such alloys include aluminum, brass, and magnesium. The molten metal is still contained in an open holding pot which is placed into a furnace, where it is melted to the necessary temperature. However, this holding pot is kept separate from the die casting machine and the molten metal is ladled from the pot for each casting, rather than being pumped. The metal is poured from the ladle into the shot chamber through a pouring hole. The injection system in a cold chamber machine functions similarly to that of a hot chamber machine, however it is usually oriented horizontally and does not include a gooseneck channel. A plunger, powered by hydraulic pressure, forces the molten metal through the shot chamber and into the injection sleeve in the die. The typical injection pressures for a cold chamber die casting machine are between 2000 and 20000 psi. After the molten metal has been injected into the die cavity, the plunger remains forward, holding the pressure while the casting solidifies. After solidification, the hydraulic system retracts the plunger and the part can be ejected by the clamping unit. The clamping unit and mounting of the dies is identical to the hot chamber machine. See the above paragraph for details.

Cold chamber die casting machine – Opened

Cold chamber die casting machine – Closed

Machine specifications

Both hot chamber and cold chamber die casting machines are typically characterized by the tonnage of the clamp force they provide. The required clamp force is determined by the projected area of the parts in the die and the pressure with which the molten metal is injected. Therefore, a larger part will require a larger clamping force. Also, certain materials that require high injection pressures may require higher tonnage machines. The size of the part must also comply with other machine specifications, such as maximum shot volume, clamp stroke, minimum mold thickness, and platen size. Die cast parts can vary greatly in size and therefore require these measures to cover a very large range. As a result, die casting machines are designed to each accommodate a small range of this larger spectrum of values. Sample specifications for several different hot chamber and cold chamber die casting machines are given below.
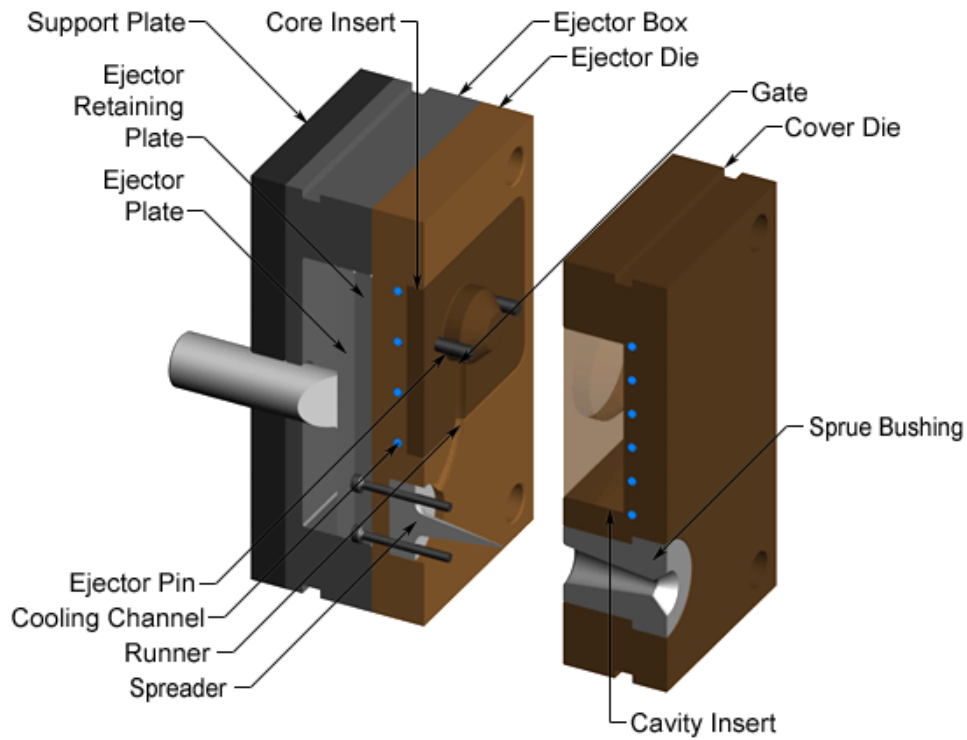
Type	Clamp force (ton)	Max. shot volume (oz.)	Clamp stroke (in.)	Min. mold thickness (in.)	Platen size (in.)
Hot chamber	100	74	11.8	5.9	25 x 24
Hot chamber	200	116	15.8	9.8	29 x 29
Hot chamber	400	254	21.7	11.8	38 x 38
Cold chamber	100	35	11.8	5.9	23 x 23
Cold chamber	400	166	21.7	11.8	38 x 38
Cold chamber	800	395	30.0	15.8	55 x 55
Cold chamber	1600	1058	39.4	19.7	74 x 79
Cold chamber	2000	1517	51.2	25.6	83 x 83

Tooling

The dies into which the molten metal is injected are the custom tooling used in this process. The dies are typically composed of two halves - the cover die, which is mounted onto a stationary platen, and the ejector die, which is mounted onto a movable platen. This design allows the die to open and close along its parting line. Once closed, the two die halves form an internal part cavity which is filled with the molten metal to form the casting. This cavity is formed by two inserts, the cavity insert and the core insert, which are inserted into the cover die and ejector die, respectively. The cover die allows the molten metal to flow from the injection system, through an opening, and into the part cavity. The ejector die includes a support plate and the ejector box, which is mounted onto the platen and inside contains the ejection system. When the clamping unit separates the die halves, the clamping bar pushes the ejector plate forward inside the ejector box which pushes the ejector pins into the molded part, ejecting it from the core insert. Multiple-cavity dies are sometimes used, in which the two die halves form several identical part cavities.
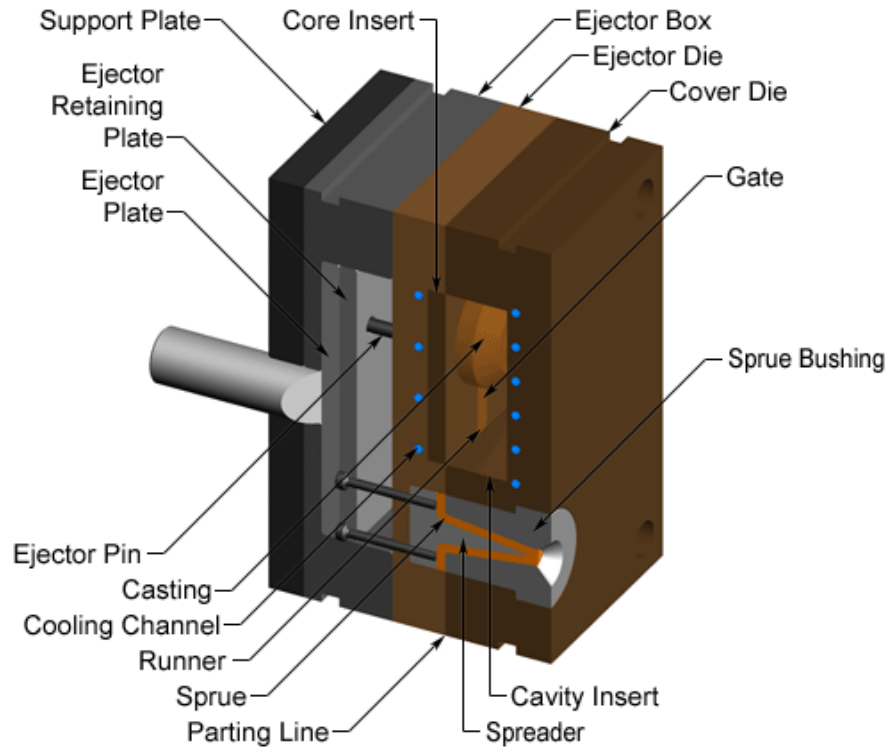
Die channels

The flow of molten metal into the part cavity requires several channels that are integrated into the die and differs slightly for a hot chamber machine and a cold chamber machine. In a hot chamber machine, the molten metal enters the die through a piece called a sprue bushing (in the cover die) and flows around the sprue spreader (in the ejector die). The sprue refers to this primary channel of molten metal entering the die. In a cold chamber machine, the molten metal enters through an injection sleeve. After entering the die, in either type of machine, the molten metal flows through a series of runners and enters the part cavities through gates, which direct the flow. Often, the cavities will contain extra space called overflow wells, which provide an additional source of molten metal during solidification. When the casting cools, the molten metal will shrink and additional material is needed. Lastly, small channels are included that run from the cavity to the exterior of the die. These channels act as venting holes to allow air to escape the die cavity. The molten metal that flows through all of these channels will solidify attached to the casting and must be separated from the part after it is ejected. One type of channel that does not fill with material is a cooling channel. These channels allow water or oil to flow through the die, adjacent to the cavity, and remove heat from the die.
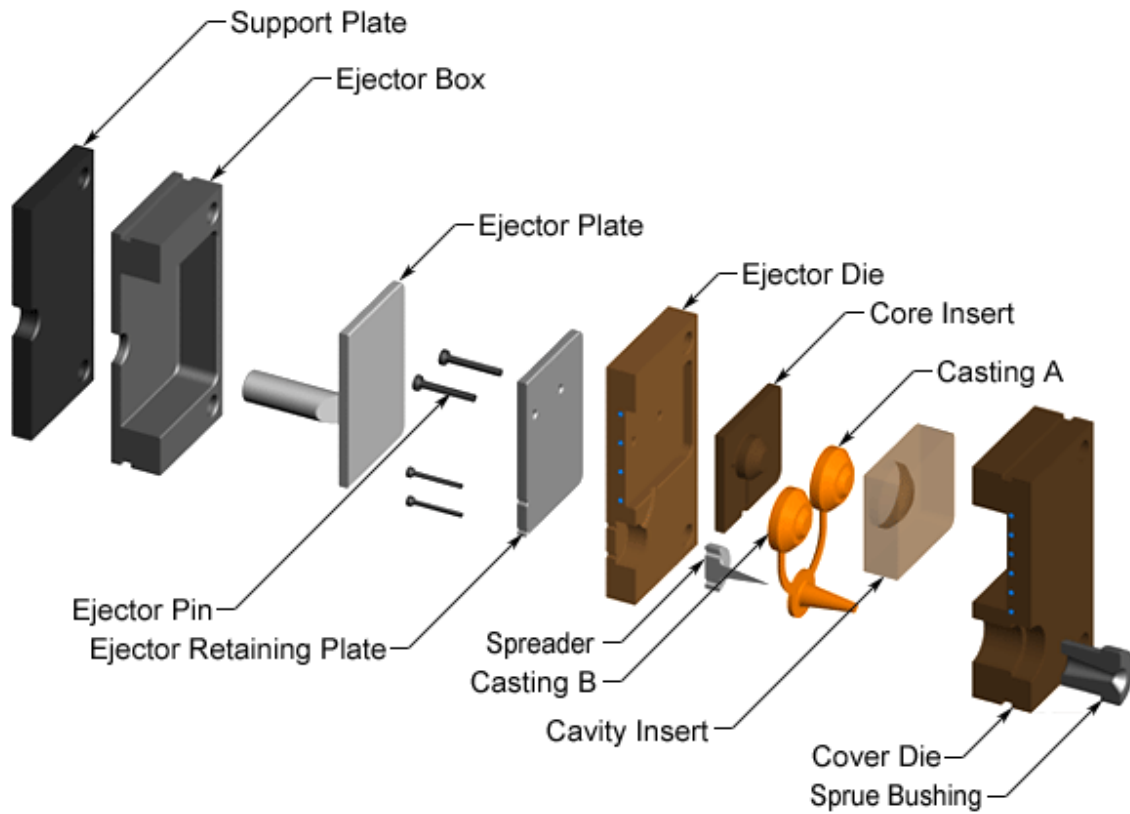
Die assembly – Open (Hot chamber)

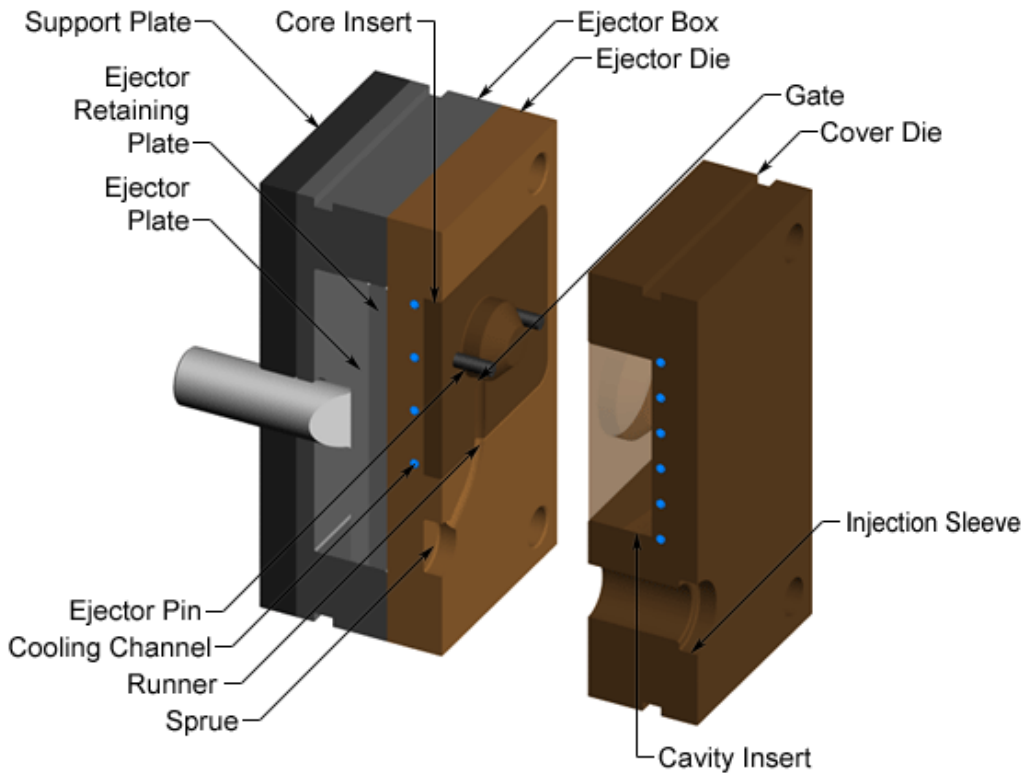Support Plate · Core Insert · Ejector Box · Ejector Die · Gate · Cover Die
Ejector Retaining Plate
Ejector Plate
Sprue Bushing
Ejector Pin
Cooling Channel
Runner
Spreader
Cavity Insert

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Die assembly – Closed (Hot chamber)

Support Plate · Core Insert · Ejector Box · Ejector Die · Cover Die
Ejector Retaining Plate
Ejector Plate
Gate
Sprue Bushing
Ejector Pin
Casting
Cooling Channel
Runner
Sprue
Parting Line
Cavity Insert
Spreader

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Support Plate

Ejector Box

Ejector Plate

Ejector Die

Core Insert

Casting A

Ejector Pin

Ejector Retaining Plate

Spreader

Casting B

Cavity Insert

Cover Die

Sprue Bushing

Die assembly - Exploded view (Hot chamber)

Die assembly – Opened (Cold chamber)

Die assembly – Closed (Cold chamber)

Die assembly - Exploded view (Cold chamber)

Die Design

In addition to these many types of channels, there are other design issues that must be considered in the design of the dies. Firstly, the die must allow the molten metal to flow easily into all of the cavities. Equally important is the removal of the solidified casting from the die, so a draft angle must be applied to the walls of the part cavity. The design of the die must also accommodate any complex features on the part, such as undercuts, which will require additional die pieces. Most of these devices slide into the part cavity through the side of the die, and are therefore known as slides, or side-actions. The most common type of side-action is a side-core which enables an external undercut to be molded. Another important aspect of designing the dies is selecting the material. Dies can be fabricated out of many different types of metals. High grade tool steel is the most common and is typically used for 100-150,000 cycles. However, steels with low carbon content are more resistant to cracking and can be used for 1,000,000 cycles. Other common materials for dies include chromium, molybdenum, nickel alloys, tungsten, and vanadium. Any side-cores that are used in the dies can also be made out of these materials.

Materials

Die casting typically makes use of non-ferrous alloys. The four most common alloys that are die cast are shown below, along with brief descriptions of their properties. (Follow the links to search the material library).

Materials	Properties
Aluminum alloys	• Low density • Good corrosion resistance • High thermal and electrical conductivity • High dimensional stability • Relatively easy to cast • Requires use of a cold chamber machine
Copper alloys	• High strength and toughness • High corrosion and wear resistance • High dimensional stability • Highest cost • Low die life due to high melting temperature • Requires use of a cold chamber machine
Magnesium alloys	• Very low density • High strength-to-weight ratio • Excellent machinability after casting • Use of both hot and cold chamber machines
Zinc alloys	• High density • High ductility • Good impact strength • Excellent surface smoothness allowing for painting or plating • Requires such coating due to susceptibility to corrosion • Easiest to cast • Can form very thin walls • Long die life due to low melting point • Use of a hot chamber machine

The selection of a material for die casting is based upon several factors including the density, melting point, strength, corrosion resistance, and cost. The material may also affect the part design. For example, the use of zinc, which is a highly ductile metal, can allow for thinner walls and a better surface finish than many other alloys. The material not only determines the properties of the final casting, but also impacts the machine and tooling. Materials with low melting temperatures, such as zinc alloys, can be die cast in a hot chamber machine. However, materials with a higher melting temperature, such as aluminum and copper alloys, require the use of cold chamber machine. The melting temperature also affects the tooling, as a higher temperature will have a greater adverse effect on the life of the dies.

Possible Defects

| Defect	Causes
Flash	• Injection pressure too high • Clamp force too low
Unfilled sections	• Insufficient shot volume • Slow injection • Low pouring temperature
Bubbles	• Injection temperature too high • Non-uniform cooling rate
Hot tearing	• Non-uniform cooling rate
Ejector marks	• Cooling time too short • Ejection force too high

Many of the above defects are caused by a non-uniform cooling rate. A variation in the cooling rate can be caused by non-uniform wall thickness or non-uniform die temperature.

Design Rules

Decrease the maximum wall thickness of a part to shorten the cycle time (injection time and cooling time specifically) and reduce the part volume.
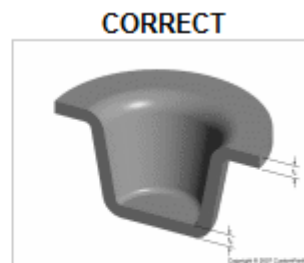
INCORRECT

CORRECT
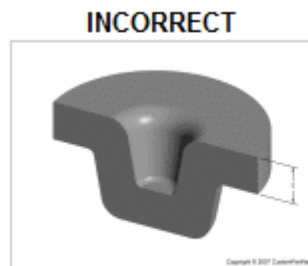
Part with thick walls
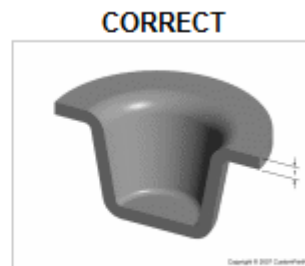
Part redesigned with thin walls

Uniform wall thickness will ensure uniform cooling and reduce defects
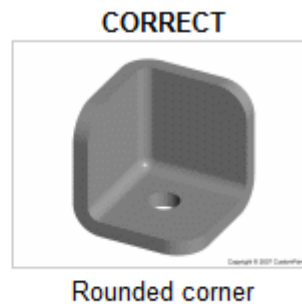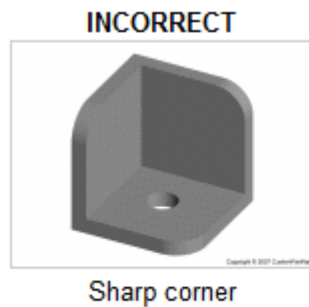
INCORRECT

CORRECT
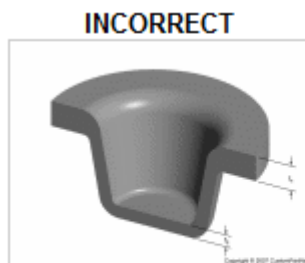
Non-uniform wall thickness ($t_1 \neq t_2$)

Uniform wall thickness ($t_1 = t_2$)

Corners

- Round corners to reduce stress concentrations and fracture
- Inner radius should be at least the thickness of the walls

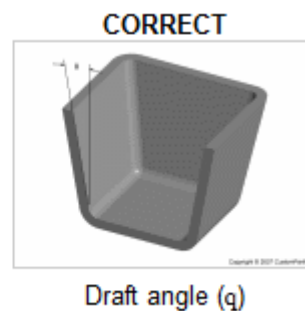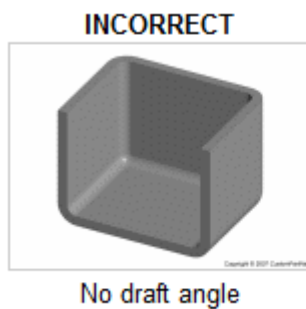| INCORRECT	CORRECT
Sharp corner	Rounded corner

Draft

- Apply a draft angle to all walls parallel to the parting direction to facilitate removing the part from the die.

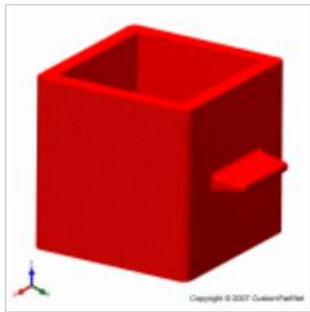 Aluminum: 1° for walls, 2° for inside cores

  Magnesium: 0.75° for walls, 1.5° for inside cores

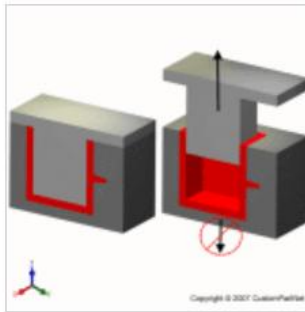 Zinc: 0.5° for walls, 1° for inside cores

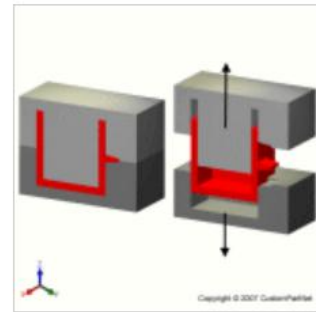| INCORRECT	CORRECT
No draft angle	Draft angle (q)

- Minimize the number of external undercuts
- External undercuts require side-cores which add to the tooling cost
- Some simple external undercuts can be cast by relocating the parting line
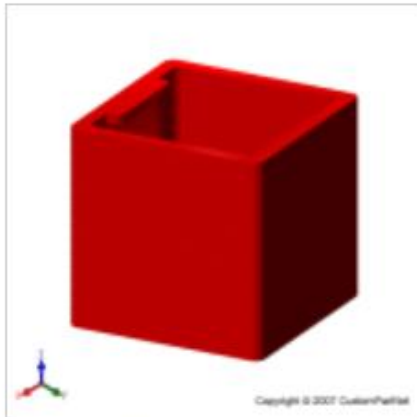

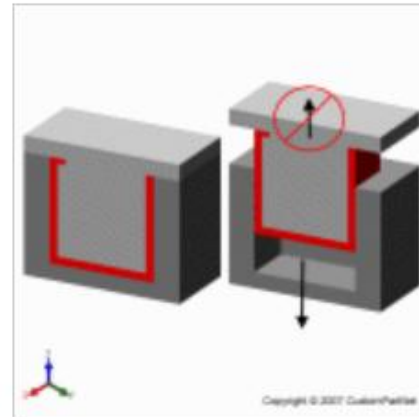Simple external undercut

Die cannot separate

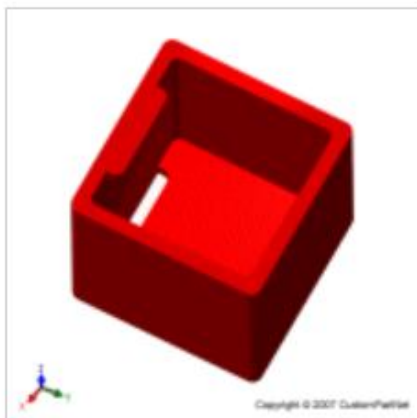New parting line allows undercut

- Redesigning a feature can remove an external undercut

Part with internal undercut

Die cannot separate

Part redesigned with slot
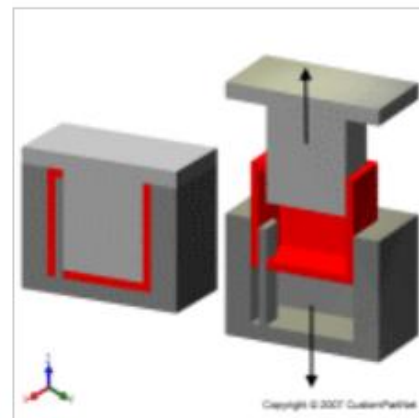
New part can be cast

- Remove all internal undercuts that require lifters - Jamming of these devices often occurs in die casting
- Designing an opening in the side of a part can allow a side-core to form an internal undercut

Access for
Side Cores
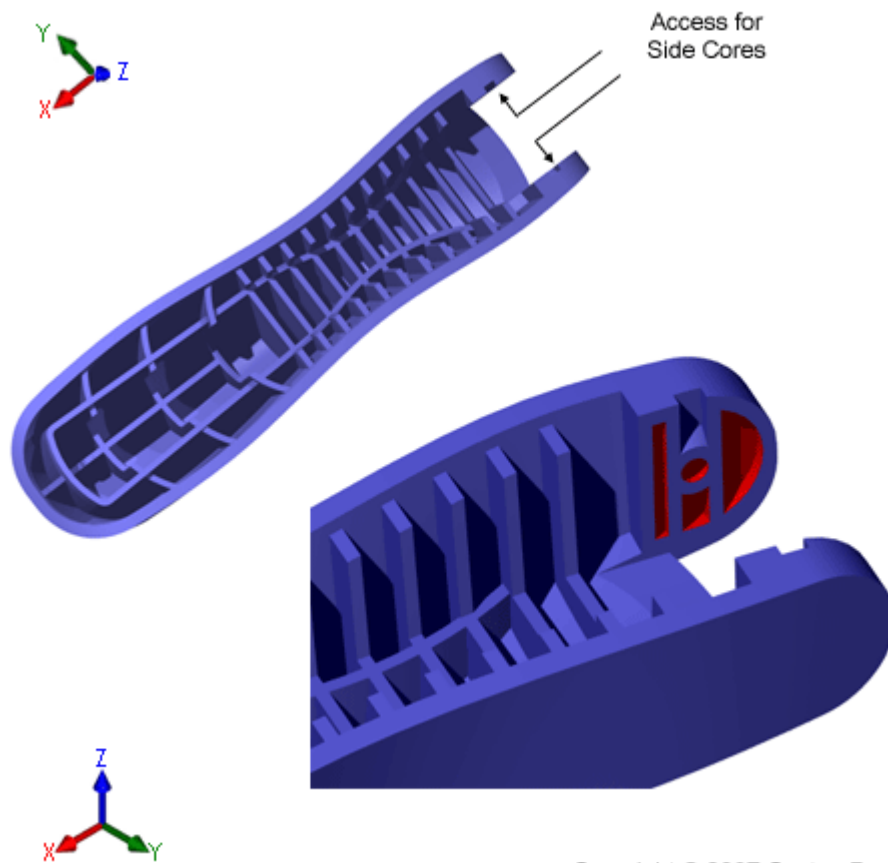
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Internal undercut accessible
from the side

Redesigning a part can remove an internal undercut

Part with internal undercut

Die cannot separate
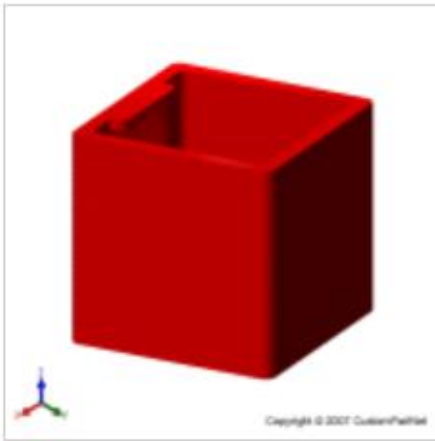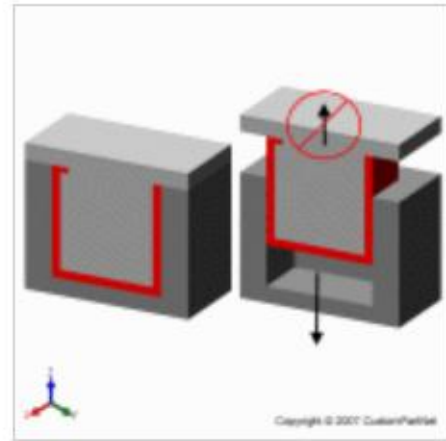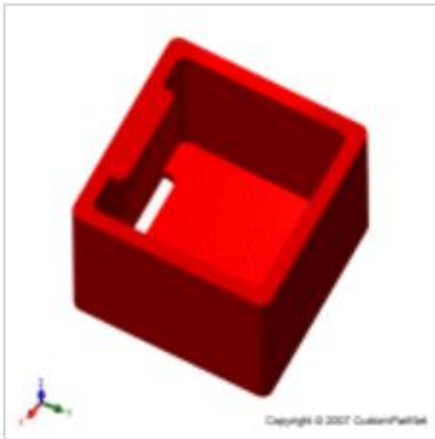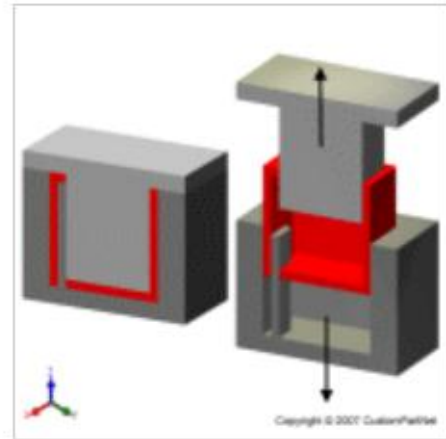

Part redesigned with slot

New part can be cast

- Minimize number of side-action directions
- Additional side-action directions will limit the number of possible cavities in the die

Cost Drivers

Material cost

The material cost is determined by the weight of material that is required and the unit price of that material. The weight of material is clearly a result of the part volume and material density; however, the part's maximum wall thickness can also play a role. The weight of material that is required includes the material that fills the channels of the die. A part with thinner walls will require a larger system of channels to ensure that the entire part fills quickly and evenly, and therefore will increase the amount of required material. However, this additional material is typically less than the amount of material saved from the reduction in part volume, a result of thinner walls. Therefore, despite the larger channels, using thinner walls will typically lower the material cost.

Production cost

The production cost is primarily calculated from the hourly rate and the cycle time. The hourly rate is proportional to the size of the die casting machine being used, so it is important to understand how the part design affects machine selection. Die casting machines are typically referred to by the tonnage of the clamping force they provide. The required clamping force is determined by the projected area of the part and the pressure with which the molten metal is injected. Therefore, a larger part will require a larger clamping force, and hence a more expensive machine. Also, certain materials that require high injection pressures may require higher tonnage machines. The size of the part must also comply with other machine specifications, such as clamp stroke, platen size, and shot capacity. In addition to the size of the machine, the type of machine (hot chamber vs. cold chamber) will also affect the cost. The use of materials with high melting temperatures, such as aluminum, will require cold chamber machines which are typically more expensive.

The cycle time can be broken down into the injection time, cooling time, and resetting time. By reducing any of these times, the production cost will be lowered. The injection time can be decreased by reducing the maximum wall thickness of the part. Also, certain materials can be injected faster than others, but the injection times are so short that the cost saving are negligible. Substantial time can be saved by using a hot chamber machine because in cold chamber machines the molten metal must be ladled into the machine. This ladling time is dependent upon the shot weight. The cooling time is also decreased for lower wall thicknesses, as they require less time to cool all the way through. Several thermodynamic properties of the material also affect the cooling time. Lastly, the resetting time depends on the machine size and the part size. A larger part will require larger motions from the machine to open, close, and eject the part, and a larger machine requires more time to perform these operations. Also, the use of any side-cores will slow this process.

Tooling cost

The tooling cost has two main components - the die set and the machining of the cavities. The cost of the die set is primarily controlled by the size of the part's envelope. A larger part requires a larger, more expensive, die set. The cost of machining the cavities is affected by nearly every aspect of the part's geometry. The primary cost driver is the size of the cavity that must be machined, measured by the projected area of the cavity (equal to the projected area of the part and projected holes) and its depth. Any other elements that will require additional machining time will add to the cost, including the feature count, parting surface, side-cores, tolerance, and surface roughness. The quantity of parts and material used will affect the tooling life and therefore impact the cost. Materials with high casting temperatures, such as copper, will cause a short tooling life. Zinc, which can be cast at lower temperatures, allows for a much longer tooling life. This effect becomes more cost prohibitive with higher production quantities. One final consideration is the number of side-action directions, which can indirectly affect the cost. The additional cost for side-cores is determined by how many are used. However, the number of directions can restrict the number of cavities that can be included in the die. For example, the die for a part which requires 3 side-core directions can only contain 2 cavities. There is no direct cost added, but it is possible that the use of more cavities could provide further saving

Common Defects In Die-Casting

Chapter 1

Basic Procedures for Controlling Defects

You can't correct and control defects without first measuring and reporting them.

The scrap reporting system must be set up for those who have to make improvements, not just for the bean counters .The scrap report should be available to everyone in the plant .In fact, it should be posted on the bulletin board so everyone can see it .

Daily scrap reports must have the following features as a minimum:

1. It must be available first thing in the morning for the previous day.

2 . It must categorize scrap (as a minimum):

- By defect type

- By part number

- By die

- By shift

- By operator

- By machine

The scrap reporting system should show long-term trends and be able to predict customer rejects based on current scrap activity – pareto charts are good ways to show the problems . The report should include defects that are not detected until the parts are downstream (such as at a machining or plating operation performed later) .A system should be developed so these defects can be tracked to the shift and the machine that produced them .All shots should be reported, even warm-up and scrap that is returned to the furnace at the machine (they cost in die life) .The process is complex, and a continuous reporting system must be set up to provide real time feedback and effective process control if defects are to be controlled .The two major defects in die casting are surface quality and porosity .Both of these require judgment decisions about severity .This means a method of measuring the severity of defects is a requirement and must be devised for many situations.The rating system is intended to tell you if the defect problems are getting better or worse, or whether changes made in the process are making a difference .What you are looking for is the ability to track any changes or trends, and to know when corrections are needed .This system also allows corrections to be made before the defect level becomes a crisis .The standards used for the rating system may not coincide with the customer standards or the quality dept .These ratings are for a different purpose and do not need to coincide .For example, you may rank a porosity defect from the worst to the best with rankings from 1 to 5.

A capability study could be done as follows:

- Take 6 sets of samples of 5 sequential castings at intervals of ½ hr. to 2 hr.

- Rate each casting and average the total. This gives the average quality level;

this should be checked against similar studies to determine if the process is improving or degenerating.

You also can use this data to estimate the standard deviation, thus obtaining a measure of the stability of the process .This kind of tracking is particularly important .Note that the person charged with correcting the defect problems might have to set up a rating system for these defects because it will be a requirement to improve defects .You can't improve it if you can't measure it.One of the most difficult problems in developing a rating system is finding a method of reporting and rating porosity. The most typical methods are fluoroscope (x-ray), machining, or sawing .A cheap and effective method is to use an old lathe to approximately duplicate the customer's machining .Always select examples for the rating system and save them .They must not be used for any other purpose .

Bottom line:

- Defect corrections must start with a good scrap reporting system.

- Developing this system starts with defining the names of defects, which means a board with samples and names of defects.

- For certain jobs, this may require setting up a rating system just for the purpose of tracking defect causes and corrections.

Chapter 2

Surface Defects

Surface Defects:

Cold flow, cold lap, chill, non-fill, swirls, etc.

Cause:

Leading edge of metal flow is too cold, laps together.

Corrections:

1 . Increase die temperature, especially at problem location .Check the following causes for cold dies:

- Slow cycle time

- Excessive coolant flow for conditions

- Excessive spray causing cold die

- Add overflows for more heat

2. Reduce fill time (caution: each action listed affects something else besides fill time: PQ2 calculations required):

- Increase plunger speed

- Increase plunger size

- Increase gate area

- Increase hydraulic pressure

3. Change flow pattern (gating):

- Direct flow at the problem area by moving the gate

- Change gate design to direct flow in a different direction

- Change gate velocity (try increase first)

- Add overflows to capture cold metal

4 . Check for low metal temperature:

- Look for delays that cool metal

- Look for furnace temperature variations (low temp swings)

- Increase temperature (carefully, other problems may appear)

5 . Low pressure at end of shot-check for:

- Dragging tips – flash around tip

- Poor sleeve condition

- Too little or inconsistent sleeve lubrication

- White (solder) buildup in shot sleeve

6 . Accumulator pre-charge pressure too low or too high

7 . Thin biscuit

8. Heavy flashing

9 . Bubbling and turbulence in hot chamber – bad rings or poor gooseneck

10 . Check also:

- Alloy–for aluminum alloys:

— Silicon at high end of range if possible

— Metal cleanliness

- Alloy–for zinc alloys:

— Aluminum content at high end

— Other constituents in range

- Vents open, and sized correctly

- Vacuum working

- Thin wall section present:

— Check for minimum wall thickness for the fill time and temperatures being used

— Design errors, designers not aware of casting problems

— Tool making errors (dimensions not as expected)

— Uneven wall section (poor part design)

Surface Defects

Typical surface defect (cold flow)

Chapter 3

Laminations

Defect:

Laminations: Layers of metal inside or outside of casting.

Cause:

Most common is poor metal flow control, though there are other causes.

Corrections:

1 . Check injection parameters:

- Fast shot start switch should start fast shot so metal is accelerated before metal gets to gate (start fast shot early)

- Quick fill time – very important, check with calculations

- Proper gate velocity

2. Gating: good flow patterns – no long flow distance and mixing far from gate .

3 . Good die temperature: should be consistent over the trouble area; best if on the high side .

4. Intensifier action proper; and consistent.

5. Die doesn't flex (die may flex from intensifier pressure) – check for adequate support .

6. Check that the lamination is not from flash left on die (often, die must be cleaned every shot) .

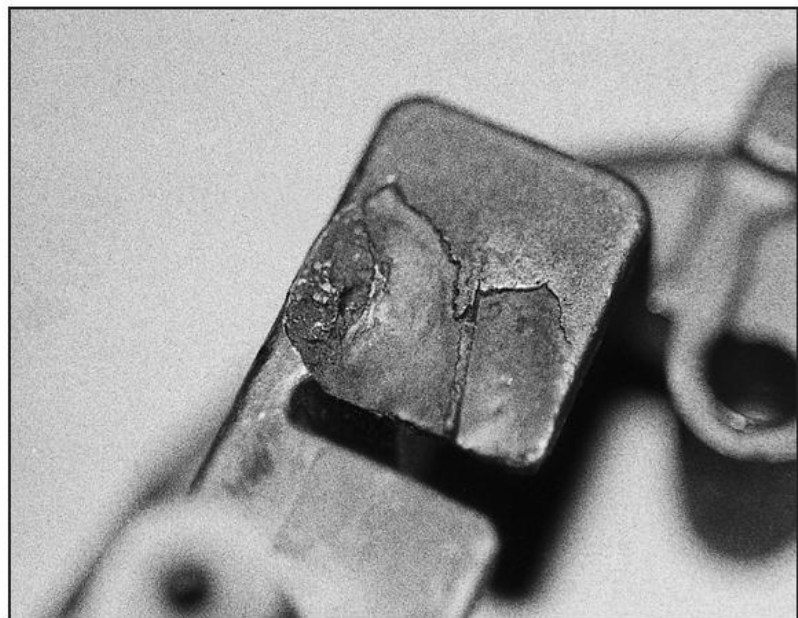7 . Examine lamination to see if it is oxide layer .

Laminations from uneven or slow flow, causing splashes with time to solidify as a layer before final fill.

These laminations were caused from the die blowing or flexing.

Flash trapped under the skin.

Chapter 4

Gas Porosity

Defect:

Gas porosity.

Cause:

Gas trapped in the metal flow during die fill.

Corrections:

1 . Gas comes from trapped air, steam or die lubricant – Check for sources of trapped air:

- Consistent pour rates

- Delay after pour – set right to minimize splashing in shot sleeve (chase the reflected wave)

- Acceleration to slow shot speed correct (use acceleration as calculated by NADCA data)

- Use critical slow shot speed

- Accelerate to fast shot speed as late as possible (this depends on situation)

2. Check runner for smooth flow path:

- No sharp corners

- No blind ends, pockets

- Ever decreasing areas properly used in runner path

3 . Check vents:

- Right size (big enough)

- Vents kept open (not full of flash)

- Located at the last point to fill, use short shots or computer predictions to locate last point to fill.

- Vents go to the edge of the die

Some typical trapped gas porosity, showing the shiny walls, as well as, shinny walls and a wall that is sometimes smooth and sometimes rough, due to oxide (10X).
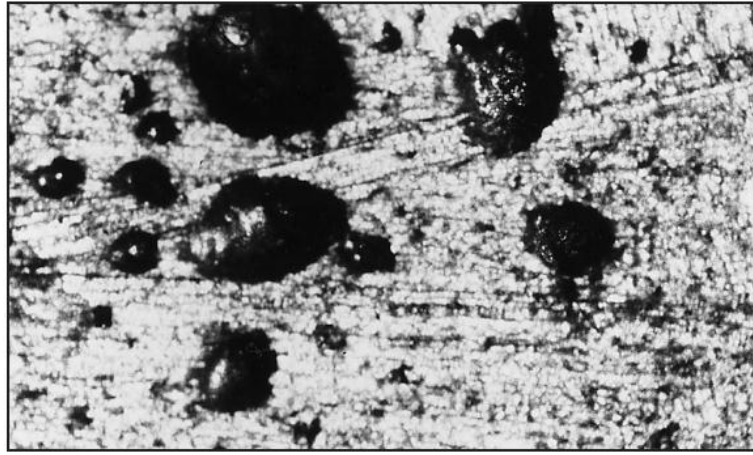
More trapped gas with a typical grouping of non-connected bubbles, and some probable dross inclusions at the bottom of one bubble (10X).

4 . Vacuum working:

- Vacuum channels big enough

- Vacuum channels located at last point to fill

- Filters cleaned and open

- Vacuum valves working

- Vacuum level adequate (must be measured and recorded, etc.)

5 . Check for gas from lubricant:

- Look for excessive plunger lubricant, (discolored castings) – be sure to run

the minimum possible amount

- Try to avoid putting lubricant in front of the tip

- Look for consistent application procedures

- Look for excessive die lubricant or anti-solder paste

6 . Check for steam (water on die):

- Check that the die is dry when it closes

- Use lots of air blow-off, both with manual and automatic systems

- Put drain holes in die where die lube (water) could accumulate

- Check for water leaks after die is locked (open die without making a shot, look for moisture)

- Lookfor leaks from sprayer, hydraulic cylinders, etc.

Chapter 5

Blisters

Defect:

Blisters.

Cause:

Gas trapped just under the surface in the metal during die fill.

Corrections:

1 . Blisters are another version of gas porosity; therefore the same correc

tions used for gas porosity will apply for blisters, i .e .:

- Reduce trapped air (see gas porosity corrections)

- Reduce spray and plunger lubricant

- Eliminate water on the die

- Correct venting and vacuum problems

2 . The most permanent solution to the blister problem is to correct the gas

porosity problem .However, as a short-term solution, blisters can be hid

den by the following actions:

- Cool the die in the immediate are where the blisters occur by:

— Cooling the blister area with die spray

— Cool the blister area by adjusting water lines

— Cool the whole die by slowing the cycle time

— Adding fountains or baffles to the blister area

3 . Cool the casting immediately after ejection by quenching in water (this

will keep the skin strong and resist blister formation) .

4 . Reduce metal temperature (but watch for other problems):

- Keep process consistent

- If blister is associated with metal swirls and captured gas from metal

flow; try to correct gating or venting problem, or add vacuum
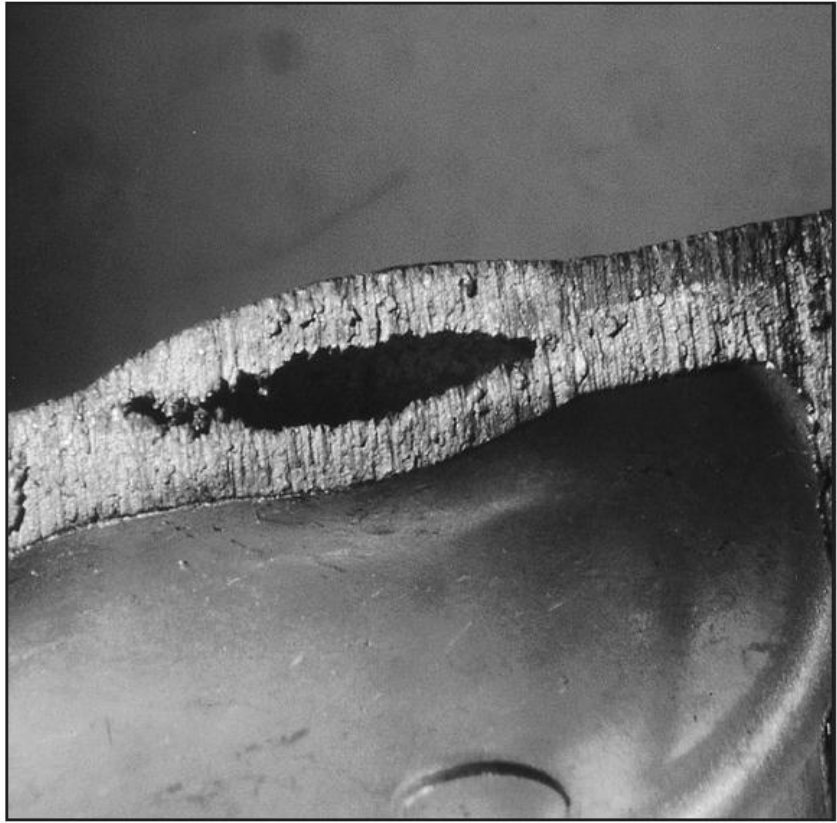
Typical blister.
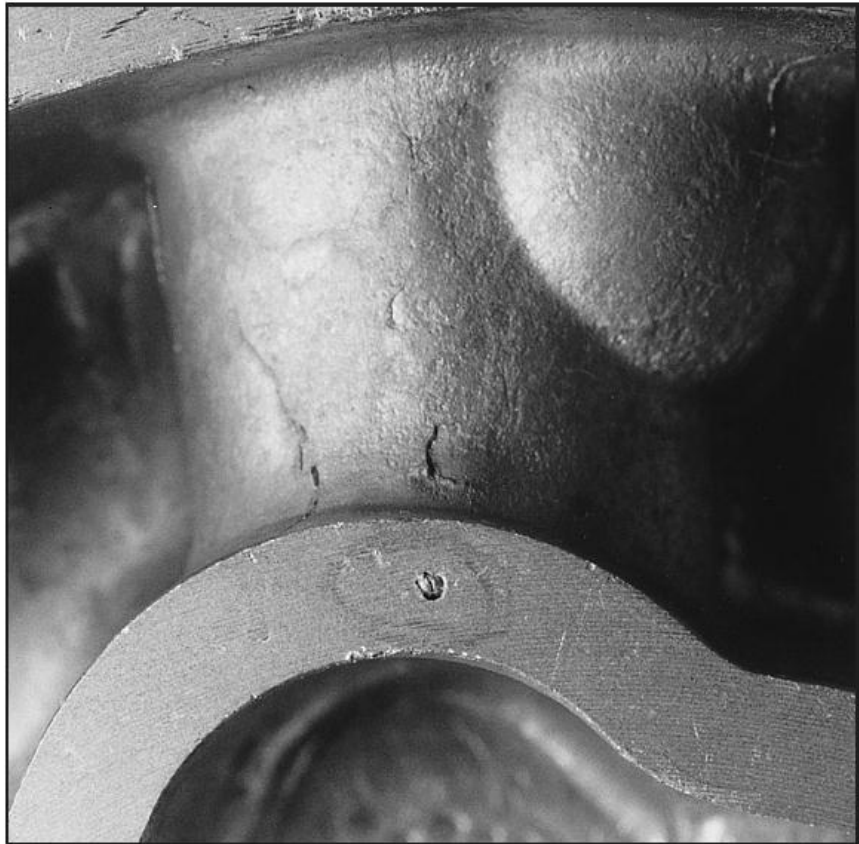
Typical blister.

Chapter 6

Flow Porosity

Defect:

Flow porosity.

Cause:

Metal flow is too slow, too cold, or has a poor flow pattern; and leaves space (porosity) between solidified metal flows.

Corrections:

1. This is a metal flow problem, so the same corrections apply as those

previously listed for surface defects (see Chapter 2) .

2. The spaces between metal flows may appear on the surface (hole) or

inside (porosity):

- The biggest factor by far is the fill time – calculate and measure to be

sure it is fast enough – if in doubt, reduce fill time as much as possible

3 . Stabilize furnace operation (reduce variation maximum of to +/- 10°F),

use the correct metal temperature:

- Metal temperature at the gate is important, in aluminum, watch for heat loss in ladle and shot sleeve – add more superheat

4 . Stabilize die temperature, and run higher die temperature (>400°F) .

5 . Review and correct metal pressures:

- Review the static metal pressure, it should be above 2000 psi for zinc,

and 3000 psi for aluminum and magnesium

- Check intensifier operation

- Consistent (most important)

- Quick enough (measure and evaluate rise time, best time will vary with casting shape)

- Pressure setting high enough (final pressure >6000 psi is alright, >9000 psi is best)

Surface from poor flow – caused by stuck plunger once every 10 shots or so.

Chapter 7

Shrinkage Porosity

Defect:

Shrinkage porosity.

Cause:

Cast material takes up less space when solid than when liquid, and this space will appear where there is a hot spot in the casting.

Corrections:

1 . Increase pressure on the semi-solid metal (at the porosity location)

during solidification.

2 . Check for pressure problems:

- Static metal pressure correct:

— >3000 min. for Al and Mg

— >2000 min. for Zn (>1500 may be alright)

- Intensifier pressure correct:

— >8000 final metal pressure is very desirable (>6000 may be alright)

- Check intensifier settings:

— Use monitor system trace to verify pressures

— Intensifier accumulator charged correctly, intensifier cylinder not bottoming, etc.

— Check rise time on monitor (set a desired standard), be sure intensifier is coming in fast enough, check switch settings

— Shot accumulator pre-charge pressure correct

- Plunger problems that reduce pressure:

— Poor tip condition (even if there is no blow by)
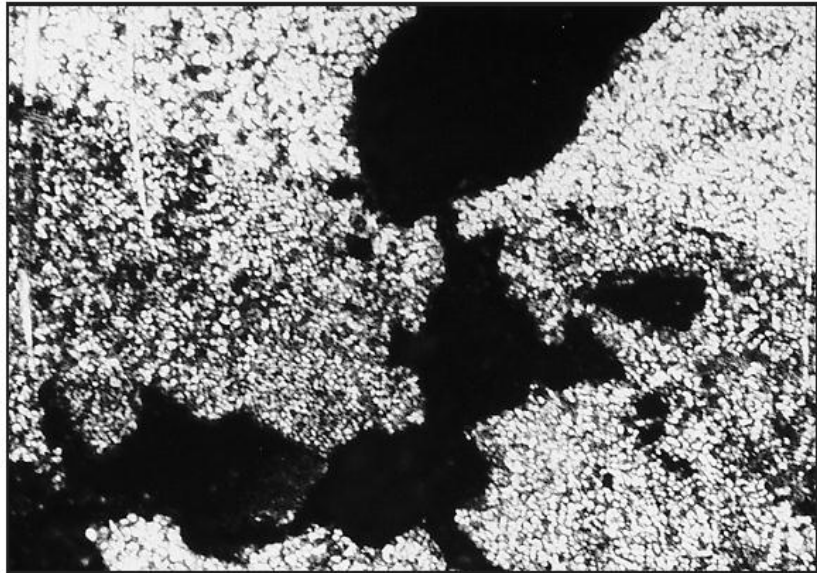
— Poor sleeve condition

— Soldering at end of sleeve

— Check for sleeve contraction from heat (sleeve squeezed by die)

Typical shrink porosity shape shown here in a sand casting because the large porosity here shows the structure clearly (1X).

Typical shrink porosity in a die casting. The dendritic structure along the edge of the porosity is barely visible (50X).

Dendritic primary aluminum crystals which formed during solidification of 380 alloy. These unusually large crystals were formed in a partially filled ladle that was left sitting in the dip well of a furnace. The temperature did not fall below the solidus temperature, which permitted the eutectic fraction to drain away (5X).
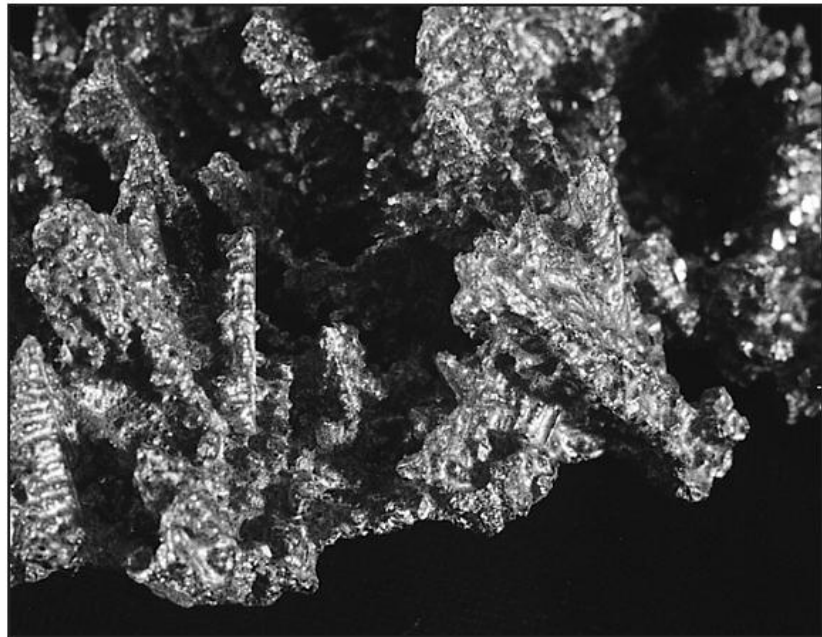
This photograph shows the rough dendritic structure on the wall of most shrink porosity (20X).

— Plunger cooling not working

— Inadequate lubrication

— Poor sleeve cooling

— Hot chamber – check plunger rings

— Hot chamber – if plunger bottoms and rings are good, change gooseneck

3 . Feed additional metal to trouble spot:

- Can squeeze pins be used?

- Can an additional gate be brought closer to the trouble spot?

- Can the wall be made thicker between the gate and the trouble spot?

4 . Thin biscuit, or biscuit size varies too much .

5 . Check temperature difference between site of porosity and surrounding area:

- Heat up surrounding cold spots

- Cool hot spot (location of porosity)

- Check temperature difference between die halves

6 . Lower temperature at injection can help, but be careful not to cause other problems .

7 . Check alloy constituents (silicon, iron) .

8. Check metal temperature fluctuations (watch for large swings, temperatures must be stable)

Chapter 8

Heat Sinks

Defect:

Heat sinks (shrinkage porosity).

Cause:

Shrinkage cracks just under surface.

Corrections:

1 . See shrinkage porosity, those techniques will work here .

2 . Cool hot spot directly where the heat sink occurs – use the following:

- Fountain (first choice)

- Die spray

3 . Thin biscuits, poor plunger conditions (hot or cold chamber) .

4 . Heat opposite side of casting:

- Shut off water

- Stop spray

5 . Check for uneven temperatures between die halves, especially in the area of the heat sink .

6. Use pressure to feed more metal during solidification to area where sink occurs:

- Adjuster intensifier

- Move gate

- Change static pressure

- Look for dragging tip (low pressure)
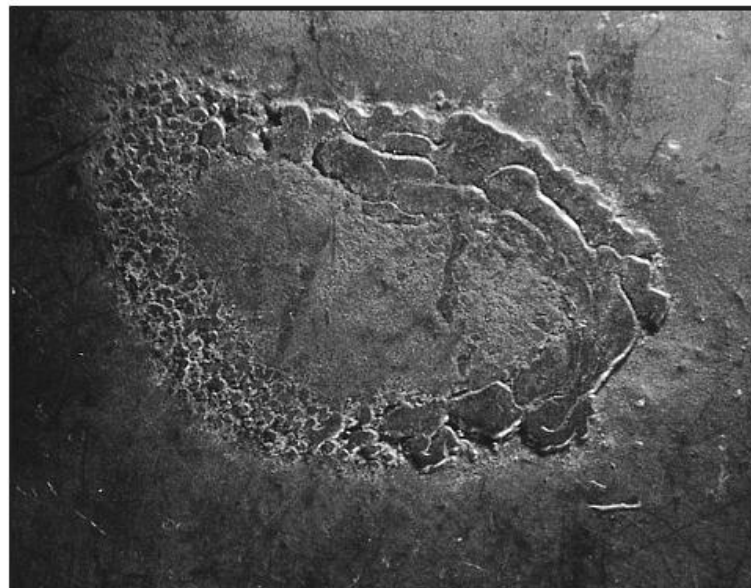
- Check accumulator pre-charge (low pressure)

Heat sink – typical appearance on a smooth surface (1X).

Fracture through a heat sink – the original shrink porosity under the skin is visible (7X).

Heat sink where some eutectic material oozed through the skin to partially fill the sunken area (5X).

Chapter 9

Leakers

**Defect:**

Leakers (shrinkage porosity).

Cause:

Loose dendritic structure inside casting is exposed by an opening in the casting skin that provides leak path (another version of shrinkage porosit y).

Corrections:

1 . Look for sharp corners at the spot where the leak occurs, add as much radius as possible .

2 . Cool with spray at the spot where the leak occurs-keep cooling even if the spray makes no difference visually .

3 . Thin biscuit, or biscuit size varies too much (can be major cause in many shops) .

4 . Try to keep skin intact in leaker area:

- Stop drags from solder or other sources

- Reduce machining if possible, keep skin intact whenever possible

5 . Try to keep skin intact in leaker area:

- Check for problems in plunger – sticking and dragging

- Poor pressure control – check static and intensified pressure

- Check intensifier performance

- Add squeeze pins in area of leakers

- Move gate closer so more pressure can be applied during solidification by intensifier

6 . Change temperature balance, cool area where leakers occur, heat areas surrounding leaker location .

Folds of oxide films, which assist in creating localized shrinkage voids and provides leakage channels through the casting wall (25X).
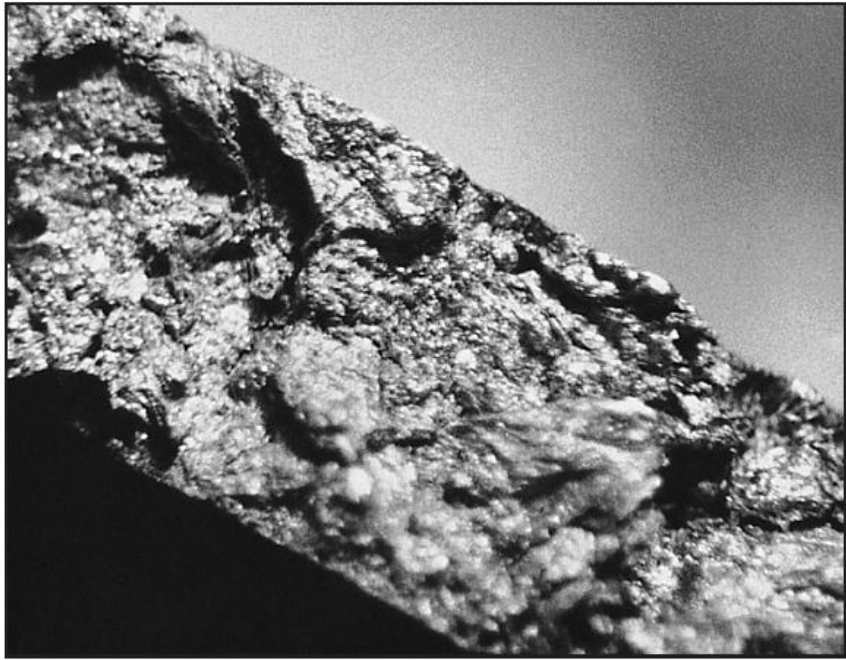
Typical internal shrinkage in a fracture through a leakage area. Note the continuous irregular paths (black) characteristic of shrinkage voids, which are interconnected through the casting wall. Normally, close inspection will show evidence of internal shrinkage by a frosty appearance or a minor cold shut on the casting surface (25X).
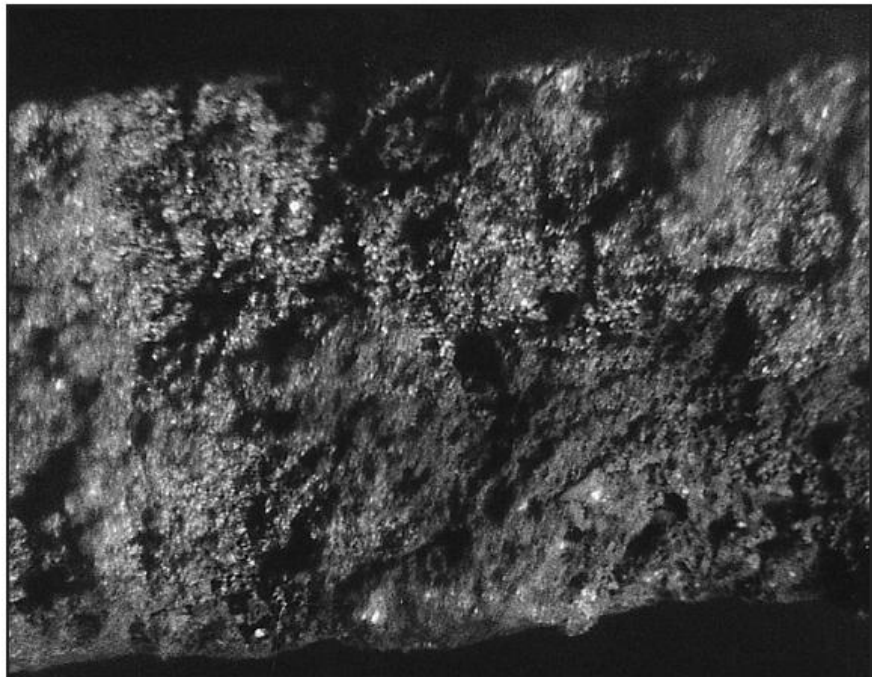
7 . Keep metal temperature consistent, and run at minimum .

8 . Check constituents in metal, don't allow variation .

9 . Keep silicon on low side .

Chapter 10

Cracks and Tears

Defect:

Cracks, tears, hot cracks.

Cause:

Many causes, from shrinkage cracks on surface, casting being stretched in the die, mechanical stress at die opening, ejection, or from trimming.

Corrections:

Determine the most probable cause first:

1 . Shrinkage cracks (surface porosity):

- Discolored crack

- Evidence of dendritic structure

2 . If shrinkage cracks are the problem:

- Check for good radii at crack location

- Cool the hot spot

- Heat up the adjacent cool spots

- Add pressure in this area during solidification (see shrinkage porosity, the same corrections apply here)

3 . For castings that crack in the die from being stretched during cooling
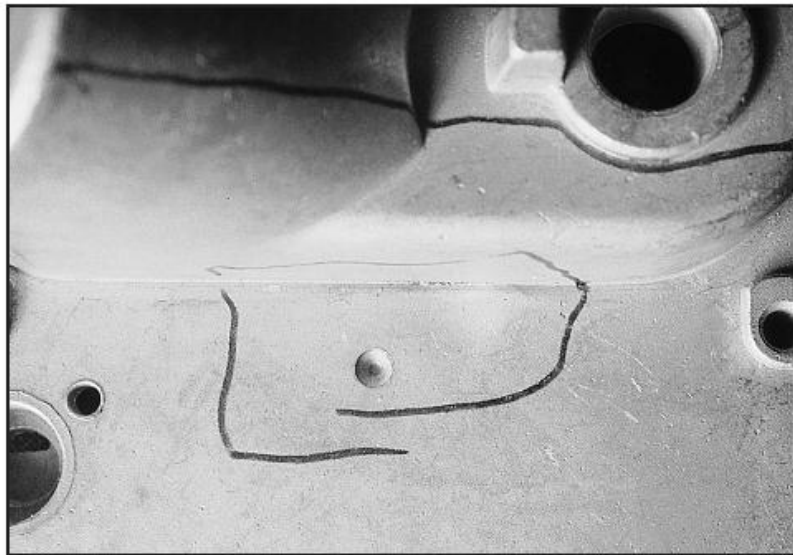
(stress cracks during cooling and after solidifying) as shown by:

- Cracks at a weak point in the shape

- Cracks at stress concentration points

- Crack surface in not oxidized

Surface cracking in a hot area, typically in an inside corner of the casting (1X).
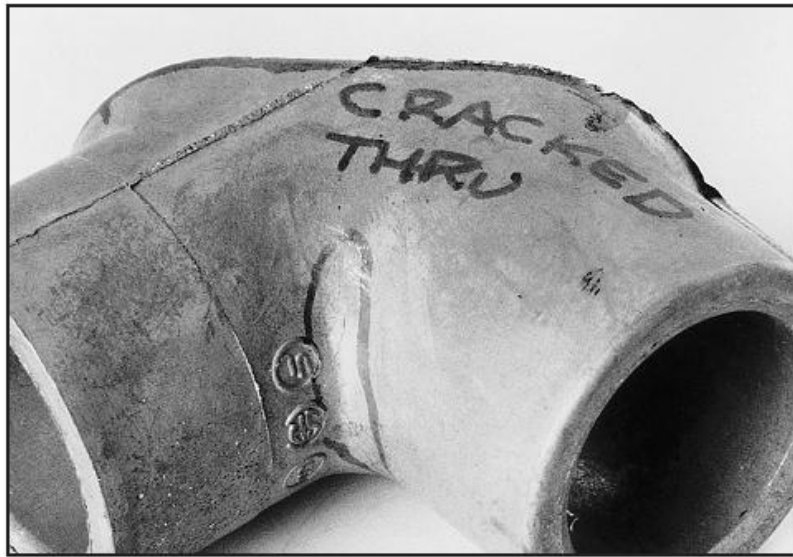
Crack at the bottom of a sink (1.5X).

4 . If this stress cracking during cooling is the problem, then:

- Reduce stress risers (add radius as much as possible)

- Shorten hold time

- Look for thin wall castings that cool before runner; in this case cool runner

and eject sooner

- Add wall thickness if possible

- If biscuit determines hold time, then add cooling to biscuit

- Change runner shape if necessary to eject sooner

5 . Identifying crack problems from mechanical forces or die shift during die opening:

- Identified by cracks at bottom of deep walls or cores – or cores or walls that stick in the cover half

- Usually have some evidence of drags

6 . Corrections for castings that crack from die shift during die opening:

- Watch as dies separate, look for evidence of die shift (ejector die drops forward as dies separate)

- Watch as dies close; If die guide pins carry the load, it is likely there is stress on the casting during opening

- Add die carrier under ejector die

- Reset die to re-align the ejector half better

- Adjust shoes under moveable platen as needed

- Check tie bar stress for even locking

- Check condition of linkage, repair as necessary

- Check condition of tie bar bushings, repair as necessary

7 . Identifying crack problems that are caused by ejection:

- Drags usually present

- Sticking problems present

- A visual check shows ejection not straight and even

- Slow down ejection process to clearly see what is happening

8 . Corrections for cracks that occur during ejection:

- Check that ejection movement is straight, guided, and does not wobble

during ejection

- Check for drags, lack of draft, or undercuts

- Eject slower and smoother

- Check slides for proper action, (slides not worn out and wobbly)

9 . Check metal constituents:

- In aluminum, check proportion of Fe, Cu, Si; also check for presence of silicon modifiers

Chapter 11

Inclusions

Defect:

Inclusions, hard spots.

Cause:

In aluminum, inclusions are mostly oxides, usually from poor melt-cleaning and furnace cleaning practices; Also can be furnace refractory. In zinc, the iron aluminum inter-metallics can lead to polishing and machining problems.

Corrections:

1 . Aluminum – the oxides were probably made in the melting furnace; check cleaning procedures:

- Examine melt line and corners for build up

- Scrape bottom for excessive corundum material on the bottom of furnace

2 . Check wall cleaning procedures:

- Proper tools?

- Operators trained?

- Is cleaning schedule discipline maintained?

3 . Check for a delay after cleaning and before delivering metal – try to get at least half hour, more is better – very important!

4. Check fluxing procedures – once/shift?

5 . Check de-gassing procedures – as often as possible

6. Check filter system:

- Filters replaces as needed?

- Filters leaking around the edges?

7. Review temperature at central melting, is it too high? (probably best between 1350-1400°F) .Use one setting; do not allow variations in settings .

Surface dross laden with large and small FeAl₃ inter-metallic particles (200X).
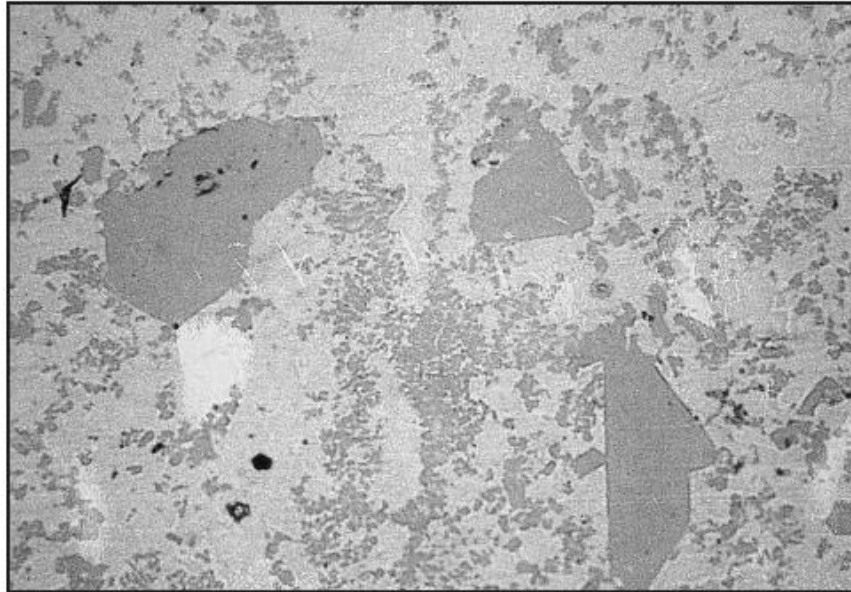
Sludge can cause machining difficulties (1X).
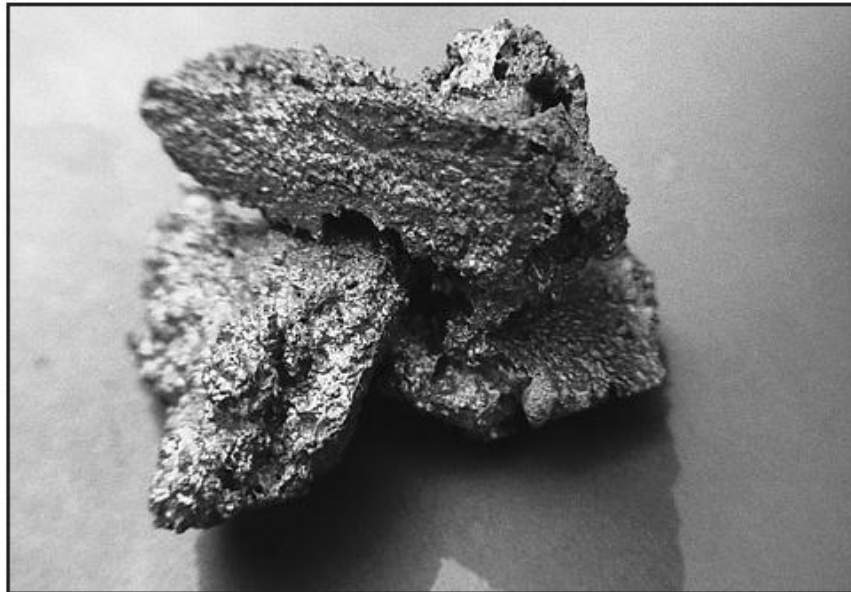
8 . Check holding furnaces for oxide build up and cleaning procedures:

- Does temperature vary too much? (look for high temp swings)

9 . It is possible that hard spots (or hard areas) will contain sludge, check bottom of furnaces and review holding furnace temperatures for sludge .

10 . Some hard spots are refractory material; this came from cleaning and then tapping the furnace too soon .

11. For zinc and ZA alloys, reduce hot spots in the pot and reduce excessive fluctuations in furnace temperature .

12 . Most of the harder material will rise to the surface as dross and can be skimmed off (if allowed to form) .

13 . For ZA alloys, keep the iron content below 0 .75% .

Chapter 12

Solder

Defect:

Solder.

Cause:

Aluminum or magnesium and die steel combine and cast metal sticks to die surface; in zinc, the zinc forms a layer on top of the steel.

Corrections:

1 . Aluminum:

— Check temperature in solder area, reduce if at all possible – this is the best solution

— Add fountain (bubbler) in solder area (even a 1/8" diameter fountain will do a good job)

— In solder area to high heat transfer material (TZM, ANVILLOY, MITECH)

— Be sure water lines are functioning (clean of deposits)

— Increase spray on the solder area

— Reduce speed, increase cycle time

- Reduce fill time

— Lower the length of time the metal impacts on the solder area

- Check the metal velocity – is it too high?

— Velocity above atomization, but not much (about 1000 to 1400 ips)

— Check PQ

2

for proper process settings, find best plunger size, speed, pressure, etc.

— Check actual plunger size and speed – are desired conditions really being met?

- Check Draft angle at solder point

- Check for undercuts or rough surface on die at solder point
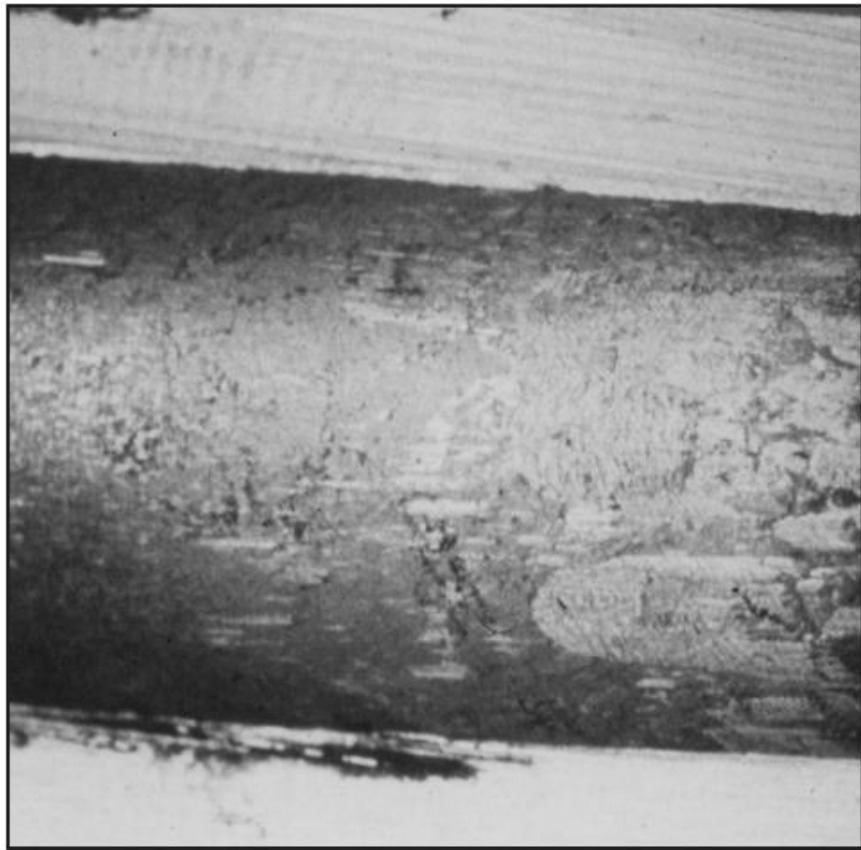
Solder on a core pin.

- Check iron content of alloy – above 0.75%

- Use lower pressure if possible

1 . Zinc (build up):

- Lower die temperature (if it can be done, this is the best action)

- Improve die surface finish – reduce surface roughness

- Increase draft angle

- Coatings – smooth surface, i.e., tin, crc

- Polish die (use inhibited acid to keep die damage to minimum, polish with

600 grit)

Chapter 13

Carbon Buildup

Defect:

Carbon Buildup.

Cause:

Build-up of deposits, usually from lubricant, or water mixed with lubricant.

Corrections:

1 . Check lubricant application:

- Spray volume is at minimum

- Increase die temperature with cycle time decreases, water flow adjustments, or spray adjustments

- Even out the die temperature, get rid of cold or hot areas

- Spray mixture and amount applied should not be varied arbitrarily, especially from shift to shift

- Use the proper lubricant to match the die temperature, especially when using a cold die (measure die temperature, verify with the supplier that the lubricant will work at the die temperature)

- Do not spray into blind fins and cores and other cold areas

- Extra spray should be carefully removed with air blow-off

2 . Do not use hard water for mixing with lubricant .

Scale buildup. Rough casting surface caused by scale or carbon buildup on the die surface (1X).

Chapter 14

Die Erosion

Defect:

Die erosion, cavitation, burn out. Die has worn spots causing raised spots on the casting; can be small deep cavities (cavitation), or larger erosion areas at the gate.

Cause:

High metal velocity, bubbles in incoming metal, high oxide or silicon content in metal.

Corrections:

1 . Check gate velocities:

- Aluminum metal velocities should be about 1000 ips to 16000 ips

- For zinc, gate velocity should be about 1200 ips to 2000 ips

- For magnesium, gate velocity should be about 1200 ips to 3000 ips (Less damage occurs from higher velocities in magnesium)

2 . Check metal temperature, should not be high .

3 . Check die temperature in the gate area, reduce with spray if possible .

4 . Check metal cleanliness, oxide cleaning procedures should be in place (see hard spots) .

5. Check fill times – long fill times accelerate gate erosion.

6 . Check alloy – hyper-eutectic (high silicon) alloys require smaller process window (lower gate velocities) .
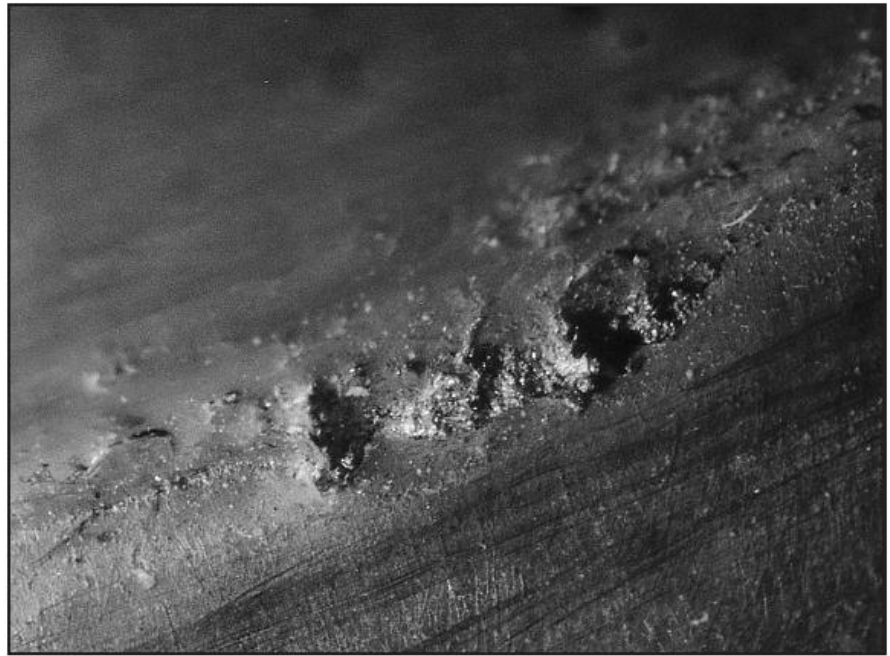
Cavitation (10X).

7 . In zinc, trapped air bubbles cause cavitation and "burn out" (see gas porosity corrections):

- Check gate design – small design mistakes that do not follow NADCA guidelines can cause cavitation

- Change gate locations, try to find a location where gate doesn't impinge on die steel

- Use slow shot speed on plunger to reduce trapped gases – set it so plunger moves slowly up to sprue
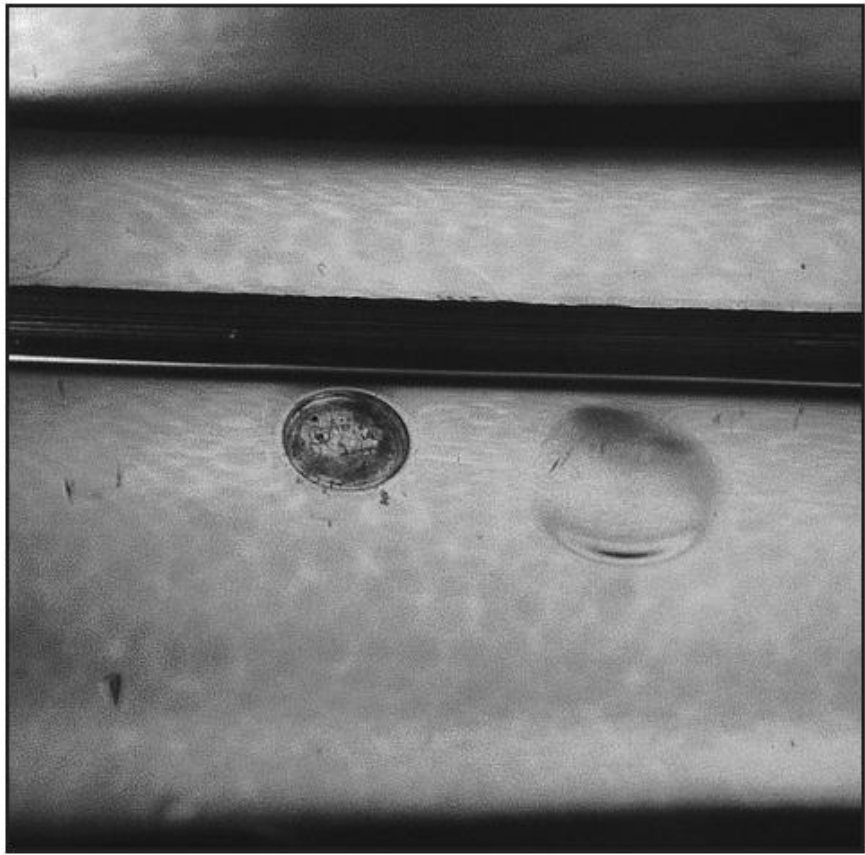
Chapter 15

Outgassing

Defect:

Outgassing: Defective surface finish occurring when bubbles appear during a painting or finishing operation.

Cause:

Leak path develops through casting skin when casting is heated during finishing, allowing the heated and expanding trapped gas to escape.

Corrections:

1. If problem is in overflow gates, then minimize or combine number or overflow gates used, reduce size of overflows.

2. Keep overflows away from edge of castings to minimize heat build up next to casting .

3 . Make main gate thinner while still maintaining appropriate gate area for casting quality needs .

4 . Reduce metal temperature, but stay above 790°F for zinc, and above about 1200°F for aluminum .

5 . Reduce die temperature at gate .

6 . Reduce trapped gas (see gas porosity corrections):

- Use slow shot speed on plunger (hot chamber)

- Reduce spray to absolute minimum

7 . Make sure there is pressure at the end of the stroke:

- No thin biscuits or leaking plunger rings

- Change or correct problems before plunger starts to stick or drag

- Check for proper metal pressure, both static pressure and intensified (right size plunger)

- Accumulator pre-charge correct

A blister and a hole (in the paint) at the gate from outgassing (4X).

Chapter 16

Edge Porosity

Defect:

Edge porosity – porosity at the gates.
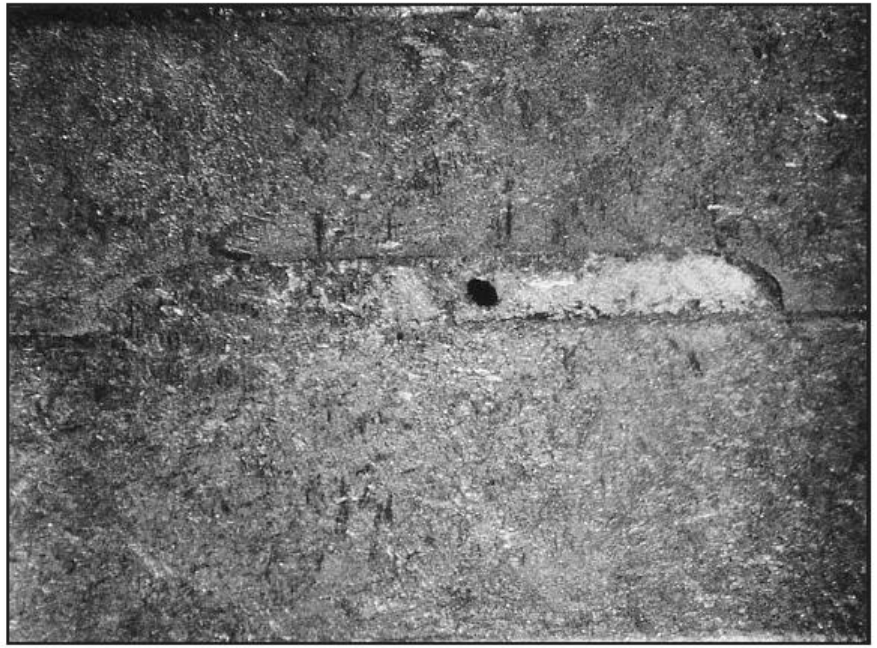
Cause:

Either shrink or gas porosity.

Corrections:

1 . Shrink porosity correction:

- The path for the gas is formed by the loose dendritic structure near the gate; this can be reduced by cooling this area more (can overcool for thin gates)

- Use long, flat gate ramps to avoid the hot steel next to the gate

- Make the gate thinner and wider to spread the heat more (don't exceed the proper gate velocity)

- Move the gate to the other half of the die if it would be cooler there

- Reduce fill time as much as possible – this reduces heat left at the gate by the metal stream

2 . Gas porosity:

- Gas porosity will contribute to outgassing, but not nearly as much as shrink porosity

- Use the techniques described in gas porosity corrections to reduce this problem (Chapter 4)

Edge porosity (6.5X).

Chapter 17

Bending, Warping

Defect:

Bending, warping, out of flatness.

Cause:

Many operational and design issues.

Corrections:

1 . Design issues:

- Too much tolerance allowance for tool construction (save most of the available tolerance for process variations)

- Incorrect shrinkage (one value for all dimensions may not be accurate enough)

- Incorrect estimate of process capabilities

2 . Operational corrections:

- The most important factor is a consistent ejection temperature; The casting and the die must be at the same temperature each time a casting is ejected

- Control hold time with a thermocouple instead of a timer

- Maintain a very consistent process to keep temperatures consistent:

— Consistent die spray

— Consistent cycle time

— Consistent cooling water flow rates
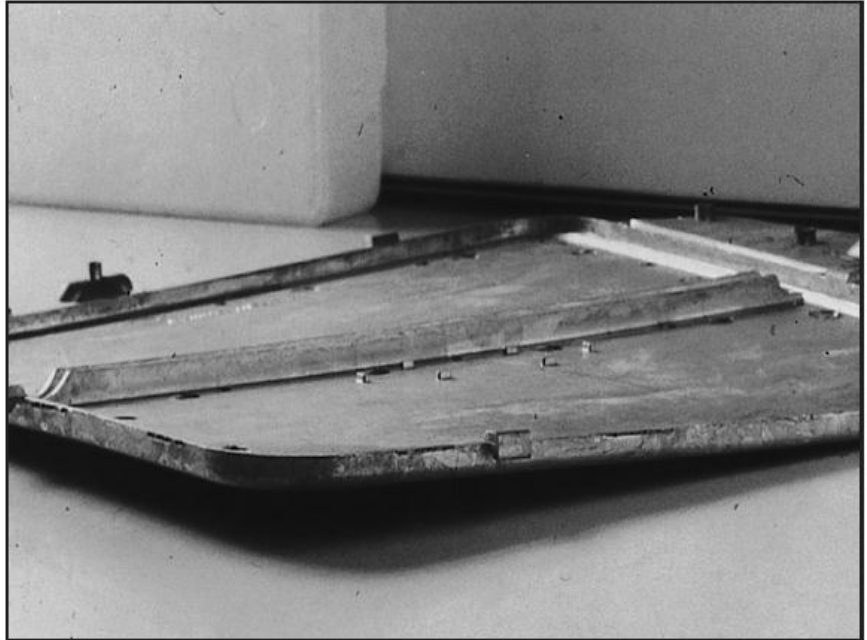
Bending. Thin casting bent at ejection.

- Uneven ejection forces:

— Poor ejector system design, or worn ejector guide mechanism

— Uneven length of bumper pins

— Incorrect ejector pin locations

— Drags from worn or heat checked die, or undercuts in the die

— Stress on casting during die opening

n Worn machine linkage

n Worn tie bar bushings

n Worn platen shoes

n No die support

n Worn guide pins

- Not enough draft allowance, especially on short walls and internal cores

- Ejection too early

- If variation is eliminated, and the casting shape is stable, then change the die dimensions so the casting comes out within specifications
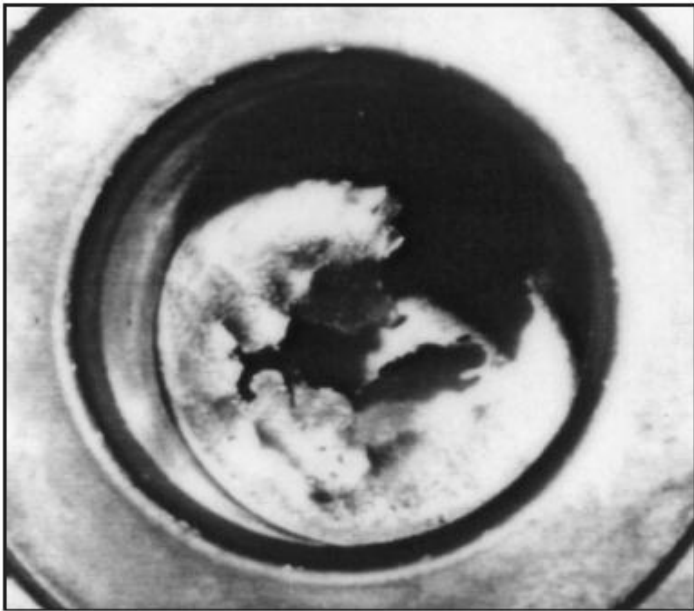
Example of excessive cast material
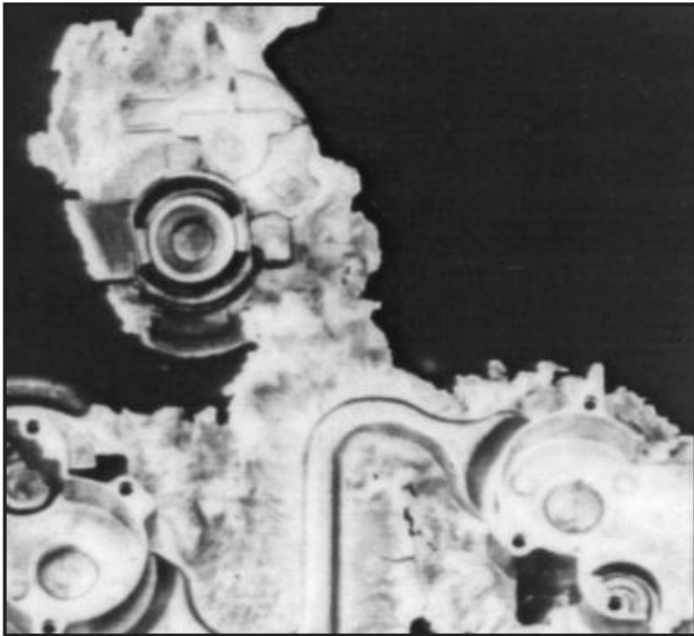
Example of very severe flash.

5 . Die and casting thermal conditions:

- Uneven heating, hot spot in casting and/or in the die – this causes the die to expand unevenly

- Be sure the hotter areas (such as the biscuit block or the are around the sprue or sleeve) have cooling

– these hotter areas can expand and hold the die open

- Heavy section of the casting on parting line in a hot section of the die

- Die temperature fluctuate from unstable operating conditions

- Metal temperatures at the gate fluctuate from unstable holding furnace or operating conditions

Chapter 19

Stained Castings

Defect:

Stained castings, discolored casting.
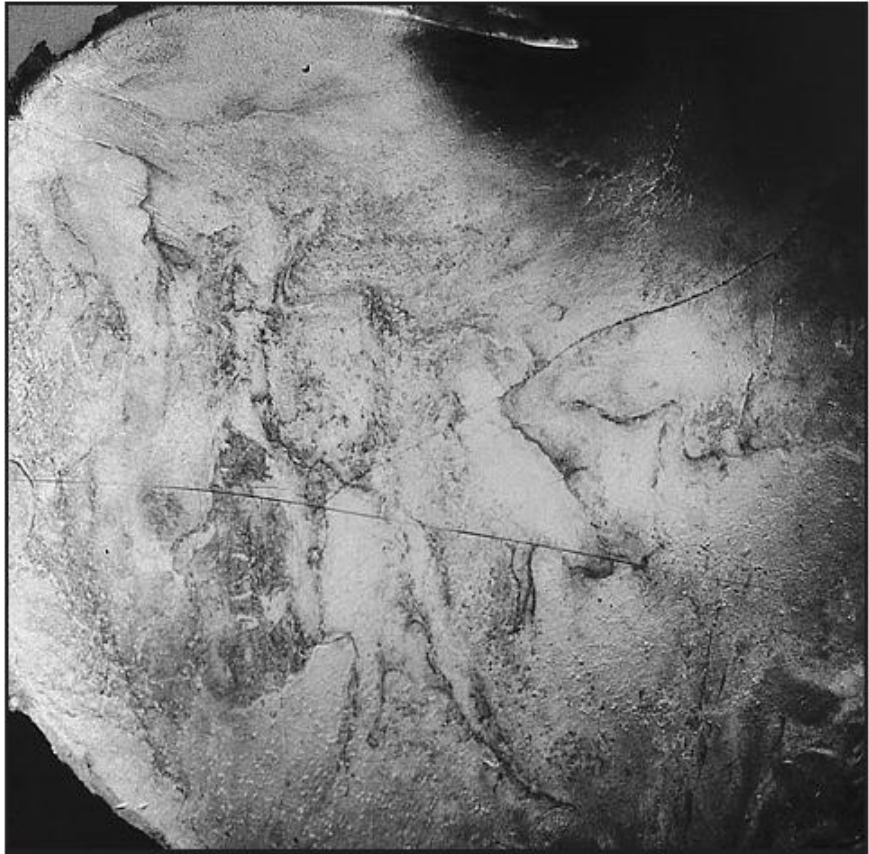
Cause:

Foreign material in the metal, almost always die lubricant, but can be other material.

Corrections:

1 . Review lubricant practices:

- Check amount of plunger lubricant

- Consistency of application (this is a major factor in many plants)

- Check amount of die lubricant used

- Check mixture ratio

- Possible look for a different lubricant material

2 . Look for other material in liquid metal – possible from scrap .

Staining from die lubrication (0.5X).

Chapter 20

Waves and Lakes

Defect:

Waves, lake.

Cause:

Usually seen in decorative zinc castings, caused by early metal flows that solidify quickly leaving a separate skin that is not remelted; the surface of this area is more fine grained than the rest and has a slightly different appearance.

Corrections:

1. Correct metal flow:

- Much quicker fill time

- Change flow pattern to minimize splashing and jetting in the area
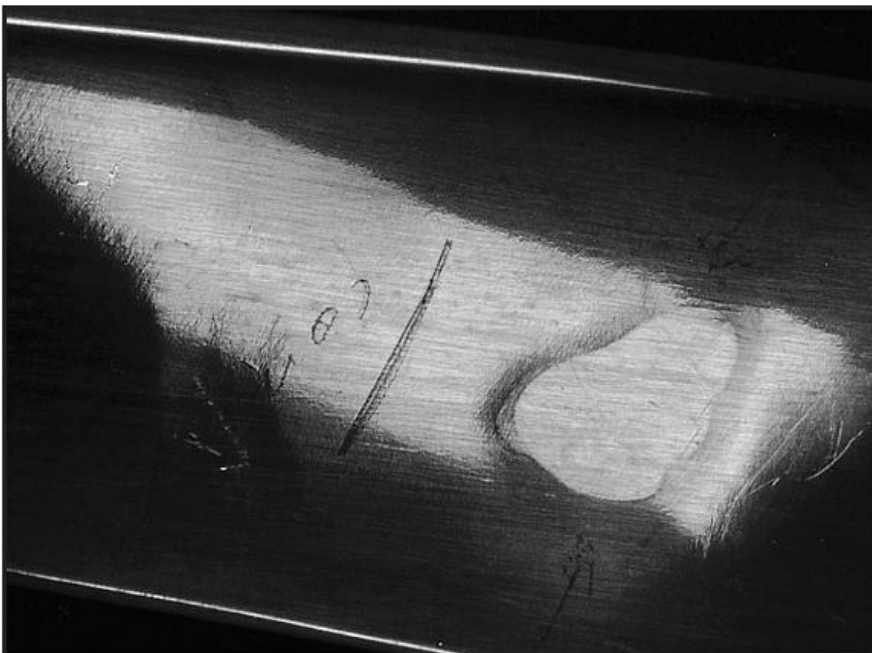
Lake seen when a section of the casting was polished; this would have caused a defect if the casting had been plated.

Chapter 21

Drags

Defect:

Drags.

Cause:

Deformation of the casting by undercuts encountered during ejection. Undercuts may be caused by buildup on the die or by die erosion of solder.

Corrections:

1 . See corrections for build-up, solder and erosion (Chapter 12 and 14) .

2 . Make sure die surface is smooth, machining marks have been completely polished out .

3 . Check draft angles .

4 . Reduce the temperature of the steel that has the drag – this can be done with spray or with high heat transfer die materials .

5 . Check metal temperature .

Drag starting in a hot corner close to the gate.

Chapter 22

Deformation from Ejector Pins
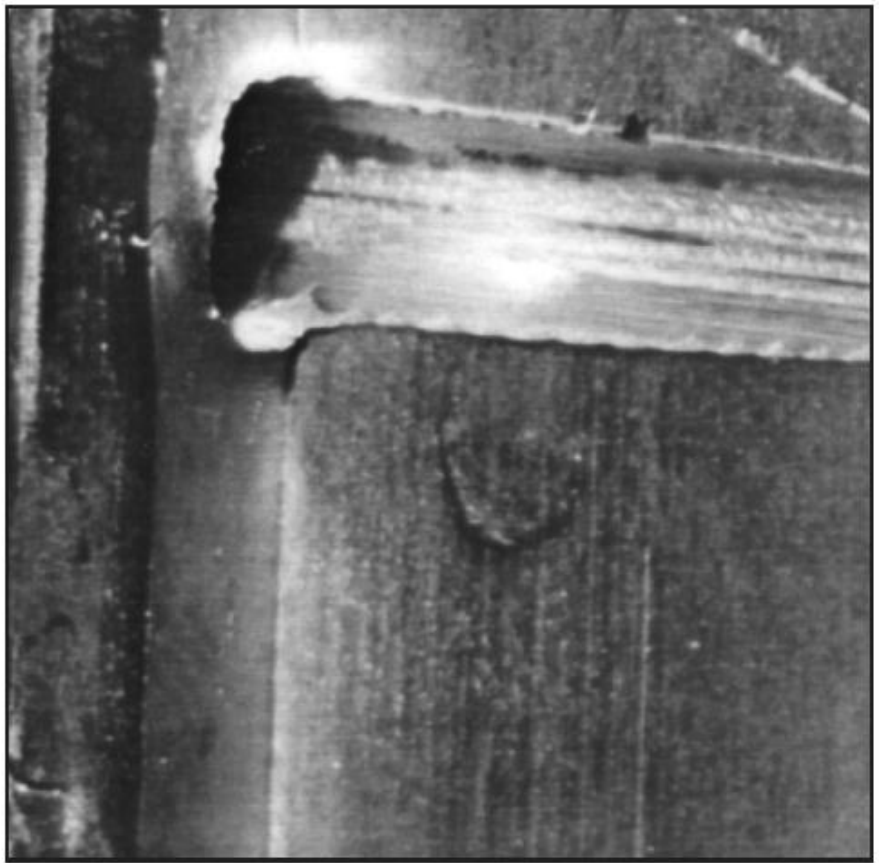
Defect:

Deformation from ejector pins.

Cause:

Caused when the casting is still soft and sticks in the die; consequently the ejector pins bend the casting trying to eject.

Corrections:

Check the following

1 . Undercuts, drags .

2 . Casting stays in the die too long or too short (hold or dwell time not correct for casting) .

- Short dwell time means the casting may be too soft at ejector pin location and may deform

- Long dwell time for certain shapes may mean that the part has contracted onto the die steel, and thus requires extra ejector force to remove

3 . Machine ejection system is "jerky," with high impact on the casting .

4 . Poor die design, check for:

- Too few ejector pins

- Pins in the wrong locations (must be balanced force around cores and other ejection resistant features)

- Use ribs under ejector pins to spread the load

- Ejector pins too small

- Ejection guidance system inadequate or worn out (ejector plate wobbles during ejection)

- Ejection system load not balanced, or if unbalanced ejection load is required, the ejector plate guidance system design was not adequate for the off center loading

Deformation from ejector pins.

Chapter 23

Excessive Flux

Defect:

Excessive flux.

Cause:

Too much flux causes an increase in porosity and surface corrosion; this is determined by putting casting in clean water overnight or examining a fracture through the porosity area for white spots.

Corrections:

Reduce flux usage:

1 . Review procedures with experts, determine the correct amount to use, and the correct application procedures .

2 . Write down procedures .

3. Train operators carefully about how much flux to use and how to apply it.
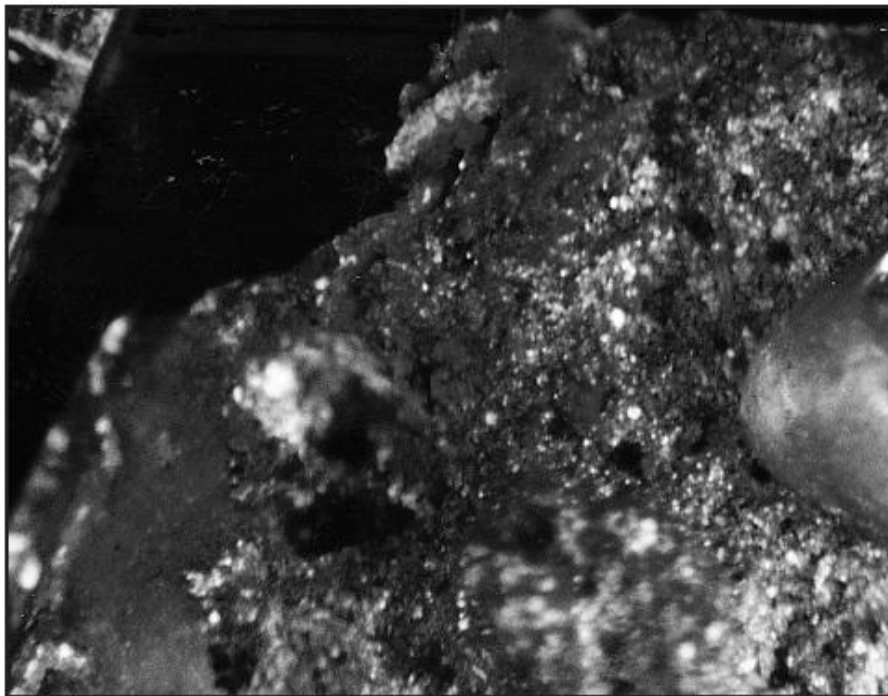
Flux inclusion in the shape of an egg shell, which broke when a fracture was made for examination (15X).