DEFECTS IN ZINC DIE CASTING

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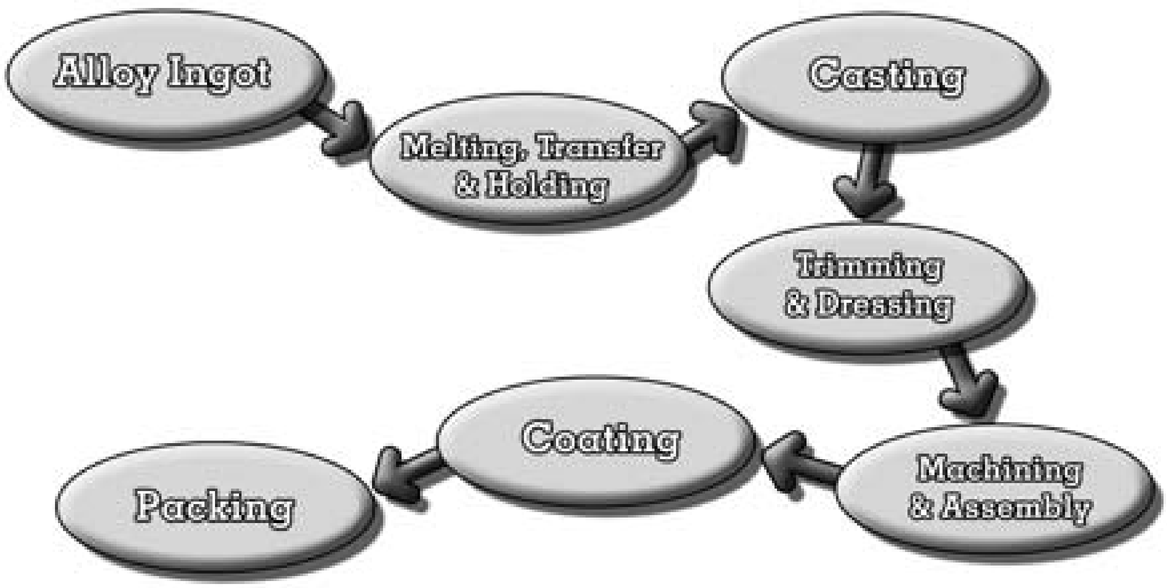
DEFECTS IN ZINC DIE CASTING

High pressure die casting is like the flight of the bumblebee, theoretically both should be impossible. However, 150 years of successful operation, with ever-increasing productivity and component quality, have shown that in practice pressure diecasting is inherently stable and can achieve high levels of process capability. Even so, scrap still occurs, even in the best run shops, and this manual covers the identification, causes, and control of the defects which may occur in zinc die castings.

There are various ways in which defects can be grouped in order to provide a coherent treatment of the subject. The approach used in this manual is to go through the sequence of operations from receiving alloy ingot to dispatch of finished product and to present information on each type of defect at the point at which it occurs. Other ways of classifying defects and various fault-finding systems are mentioned later. The process stages considered are listed below:



In addition there will be the recycling of runners and of scrap arising at various stages, and inter-process storage and handling also has to be considered. Not all castings will go through all the processes.

Ingot Specification

The compositions of zinc casting alloys have been painstakingly developed over a seventy-five year period. The ranges of the alloying elements have been optimised and the maxima for harmful impurities have been carefully set. To produce reliable castings, ingot conforming to internationally accepted specifications must be used. In addition, the alloy quality must be maintained throughout the melting and casting processes so that the cast components conform to the casting composition specifications. The small differences between the ingot (Table 1) and the casting (Table 2) specifications for each alloy type are to safely allow for variation induced by normal processing and recycling practices.

The use of off-specification ingot, especially that contaminated with very harmful impurities such as lead, tin or cadmium, is never justified.

The alloys fall into three families:

- the 4% aluminium alloys, Nos 3 and 5, and also Nos 2 and 7,
- the higher aluminium ZA alloys, Nos 8,12 and 27, and
- the copper alloys Acuzinc 5 and 10.

In addition there are some other alloys that have not been commercially accepted. Nearly all zinc alloy castings are made in either No3 or No5, the others are specified only when their properties are required.

Effect of Contamination

The effects of contaminating elements, eg the specific effects caused by lead on castings are similar between the alloys. The exact impurity maxima specified reflect the varying severity of the effect and the ease with which ingots may be produced with low levels of trace elements.

Lead, Tin, Cadmium

These elements, together with the similar but less likely to occur indium and thallium, can cause catastrophic failure through intergranular corrosion. The impurities segregate to the grain boundaries where they facilitate corrosion between the grains, especially in warm, humid conditions. Castings swell and break up, literally turning into piles of grey powder (figure 1).

Provided the magnesium levels are maintained above the minima the effect is negligible in castings containing up to the specified maxima of these contaminants. Correct purchasing of ingot and good housekeeping to avoid contamination from re-melt or the shop environment, eg solder, are the preventative measures.

Figure 1. *Intergranular corrosion-contamination-melting.*

Iron

Iron is only sparingly soluble in zinc and excess iron reacts with the aluminium in the alloy to form the intermetallic compound iron aluminide, $FeAl_3$. This compound is very hard and if it gets in the casting can cause machining problems, ie high tool wear; and polishing problems, ie particles will stand proud or rip out. Excessive amounts can reduce the fluidity and hence the die filling ability of the alloy. Finally, if concentrated at stressed areas the strength and ductility may be reduced. There is evidence that it is the size of the particles as much as the total amount present which governs machinability because iron comes from the melting pot. Control of metal temperature is the primary defence.

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Nickel, Chromium, Manganese, Silicon

Excessive amounts of these elements have similar effects on the casting as excess iron. Note that in alloy No 7 nickel is not a contaminant, the small amount (less than the solubility limit) specified is a deliberate addition to control intergranular corrosion in this magnesium free, high fluidity, alloy.

Effect of Alloying Elements

Aluminium

Aluminium is the major alloying addition in all alloys except the Acuzinc types. Both the strength and the castability of the alloys depend on its level being within specification. Properties can change rapidly outside the fairly narrow ranges specified, especially in alloys Nos. 2, 3, 5 and 7.

In these 4%Al alloys, excess aluminium causes a sharp decrease in the impact strength (Figure 2) so it is imperative that no aluminium be picked up during processing. If the aluminium drops below the specified minima then effects are less marked. Possible consequences are a tendency toward hot tearing and hence reduced strength, decreased fluidity, and also the increased tendency for the alloy to stick to the die (soldering).

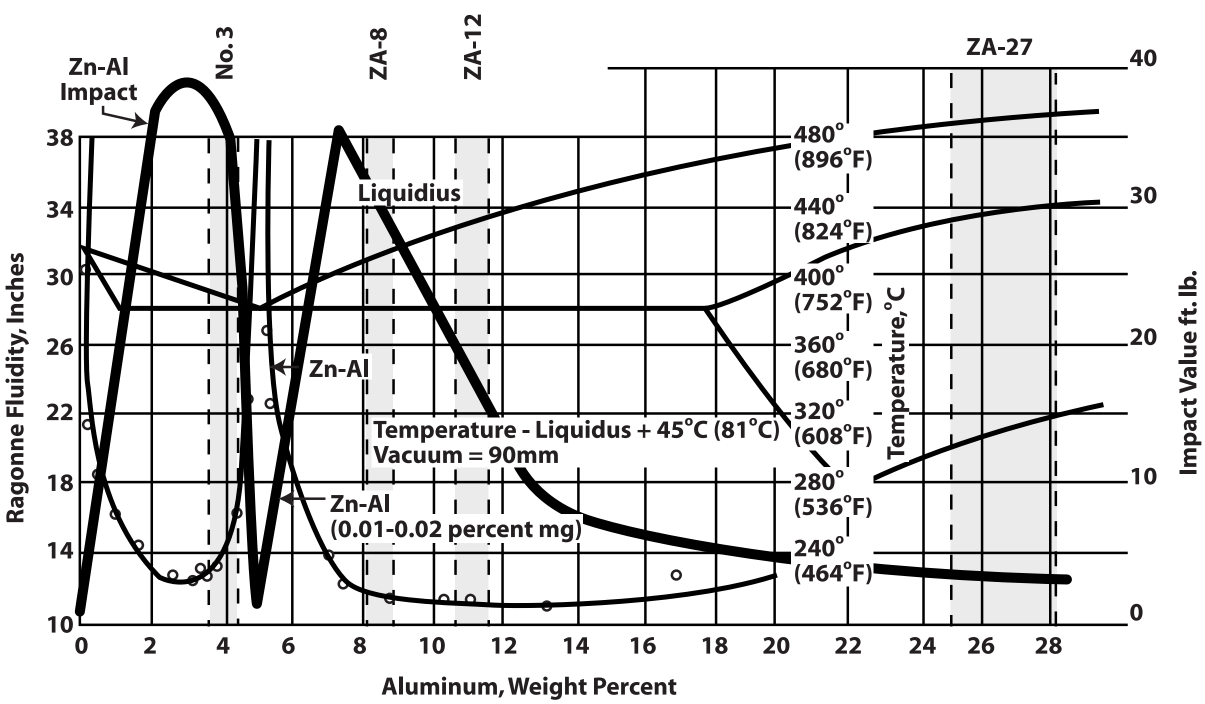

Figure 2. *Impact strength & fluidity of zinc die casting alloys.*

In the higher aluminium ZA alloys, variations in the aluminium content have a less marked effect on properties, hence the wider ranges allowed. However, like the 4% alloys, the compositions have been optimised to give the best combination of properties and going outside the limits will cause changes that may be detrimental.

Magnesium

Although the magnesium addition has a strengthening effect, its main purpose is to ensure that intergranular corrosion does not take place in alloys that happen to contain lead, tin etc. at levels up to the permitted maxima. Hence castings containing less magnesium than the range minimum could suffer corrosion in service. A magnesium content above the maximum range can give rise to hot tearing with a consequent loss of strength or coating problems. High magnesium also reduces the fluidity of the alloy that may cause filling problems.

Copper

The addition of copper to the basic 4%Al alloy raises the strength and hardness at the expense of reducing ductility and making the alloys change dimension more on ageing. High copper alloys also show a decrease in impact strength on ageing. Hence, alloys that fall outside the relevant copper limits will have properties intermediate between the standardised alloys.

The copper content of the ZA alloys has a strong influence on the mechanical properties. In general, high copper causes a decrease in ductility whereas low copper leads to a decrease in tensile strength.

	Alloy Designation						
Element	2	3	5	7	ZA-8	ZA-12	ZA-27
Al	3.9-4.3	3.9-4.3	3.9-4.3	3.9-4.3	(8.2-8.8)	(10.8-11.5)	(25.5-28.0)
Mg	.025-.050	.025-.050	.03-.06	.01-.02	(.020-.030)	(.020-.030)	(.012-.020)
Cu	2.6	.10 max	.75-1.25	.10 MAX	(.8-1.3)	(.5-1.2)	(2.0-2.5)
Fe (max)	.075	.075	.075	.075	(.065)	(.065)	(.072)
Pb (max)	.004	.004	.004	.002	(.005)	(.005)	(.005)
Cd (max)	.003	.003	.003	.002	(.005)	(.005)	(.005)
Sn (max)	.002	.002	.002	.001	(.002)	(.002)	(.002)
Ni	-	-	-	.005-.020	-	-	-
Zn	Balance	Balance	Balance	Balance	Balance	Balance	Balance
SOURCE	ASTM B240	ASTM B240	ASTM B240	ASTM B240	ASTM B669-95	ASTM B669-95	ASTM B669-95

Note: Zinc alloy die casting may contain nickel, chromium, silicon, and manganese for amounts of 0.2, 0.2, 0.35, and 0.5%, respectively. No harmful effects have ever been noted because of these elements in these concentrations.

Table 1. *Composition of zinc pressure die casting alloys ingot limits, % by weight.*

	Alloy Designation						
Element	2	3	5	7	ZA-8	ZA-12	ZA-27
Al	3.5-4.3	3.5-4.3	3.5-4.3	3.5-4.3	8.0-8.8	10.5-11.5	25.0-28.0
Mg	.02-.05	.02-.05	.03-.08	.005-.020	.015-.030	.015-.030	.010-.020
Cu	2.5-3.0	.25 max	.75-1.25	.25 max	.8-1.3	.5-1.2	2-2.5
Fe (max)	.10	.10	.10	.075	.075	.075	.075
Pb (max)	.005	.005	.005	.003	.006	.006	.006
Cd (max)	.004	.004	.004	.002	.006	.006	.006
Sn (max)	.003	.003	.003	.001	.003	.003	.003
Ni	-	-	-	.005-.020	-	-	-
Zn	Balance	Balance	Balance	Balance	Balance	Balance	Balance
SOURCE	ASTM B86	ASTM B86	ASTM B240	ASTM B86	ASTM B791	ASTM B791	ASTM B791

Note: Zinc alloy die casting may contain nickel, chromium, silicon, and manganese for amounts of 0.2, 0.2, 0.35, and 0.5%, respectively. No harmful effects have ever been noted because of these elements in these concentrations.

Table 2. *Composition of zinc pressure die casting alloys casting limits, % by weight.*

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In the Acuzinc alloys, the copper is the primary alloying addition and confers higher hardness and increased high temperature strength compared with the other zinc based alloys. The relative copper and aluminium levels in the Acuzinc alloys have been optimised to balance properties and castability. Being in a different phase system the effect of the high copper level on dimensional ageing change may be different to that observed in the 4%Al alloys.

Metal Melting, Transfer and Holding

Except for alloys ZA-12, ZA-27 and Acuzinc10, which attack iron and steel at an unacceptable rate, the zinc alloys can be melted and held in metal containers. It is this property that allows them to be cast by the hot chamber process which uses an immersed injection system.

However this useful feature is only made possible by exercising rigorous temperature control. Below about 450°C, the rate at which the zinc alloy dissolves iron is sufficiently slow to allow the use of metal parts in contact with the alloy. The rate of reaction increases exponentially with temperature so it is sensitive to minor temperature excursions.

The reaction is between the aluminium in the alloy and the iron in the crucible and machine parts.

Aluminium + Iron > Intermetallic particle

$3Al + Fe > FeAl3$

The iron aluminide intermetallic floats to the surface and combines with the oxide layer to form dross. If the dross is stirred into the metal or if the pot level is allowed to fall so low that sub-surface metal is sucked into the gooseneck, then the casting will contain hard particles which will give rise to the defects listed under iron in the contamination section.

Excessive temperature also leads to loss of magnesium as this is a volatile element and is boiled off. Low magnesium subjects the casting to severe corrosion problems in service.

Note that it is not only the overall melt temperature that is important. If there is a hot spot in the furnace, due to a poorly adjusted burner for example, then the local high temperature will lead to iron pick-up. In severe cases the crucible may be eaten through, resulting in a run-out.

Recommended metal casting temperatures are:

Nos 2,3,5,7	415-430°C
ZA8	420-445°C
ZA12	465-495°C
ZA27	550-580°C
Acuzinc 5	~ 480°C
Acuzinc 10	~ 530°C

The ZA alloys, especially ZA-27, tend to gravity segregate into aluminium rich and zinc rich layers on melting. Vertical stirring will mix the melt; vigorous stirring should be avoided, otherwise oxidation will be encouraged. Once mixed the melt should be stable. It is imperative that any dross layer formed is not

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assumed to be segregated and stirred in. ZA-27 should not be held below 540°C because any iron in solution will precipitate as large intermetallic particles.

Provided good temperature control is observed and there is no accidental contamination, there should be no problems arising from the melting and holding of on-specification ingot. Where remelting of runners and scrap is carried out, other factors also have to be considered.

The returns have to be rigorously segregated, especially in shops that also melt aluminium alloys. Mixing some aluminium runners in with the 4% zinc alloys will result in castings containing high aluminium that will make them brittle. The same problem will arise if ZA alloy gets mixed in with standard alloy.

The direct remelting of swarf, flash and other light gauge surface contaminated material will give rise to excessive dross and the possibility of picking up contaminants. Such material is best treated separately so that the composition of the re-melt ingot can be checked. Dross should also be flux treated separately for similar reasons. The flux tends to remove magnesium, especially if the metal is overheated. Electroplated castings also need careful treatment. On melting, the electroplate skin remains on the surface and can be skimmed. It is essential that the plate is not broken up and stirred into the melt as the nickel, in particular, may then cause hard spotting.

During melting and casting the alloy suffers a slight loss in magnesium (by volatilisation) and of aluminium (by reaction with iron and hence removal as dross). Therefore, continuous remelting of the same metal would eventually give rise to out-of specification castings. Tests on No3 alloy have shown that it takes seven cycles to reduce the magnesium to less than the minimum specified. To prevent this eventual degradation, virgin ingot needs to be continuously fed into the process.

Casting

Internal Defects

Shrinkage Porosity

As the alloy passes from liquid to solid, shrinkage of several percent of the casting volume occurs. Unless additional liquid metal is available to feed this shrinkage, a void is formed. This is shrinkage porosity. It typically occurs at isolated heavy sections where it tends to be large irregular holes (figure 3) or it may, especially in long freezing range alloys such as ZA-27 and Acuzinc, be in an interdendritic, crack-like form.

The internal porosity may be exposed if surfaces such as flanges or in a bore, have to be machined, causing rejection. Porosity can also cause tool wear and drill wander in machining operations. The effect

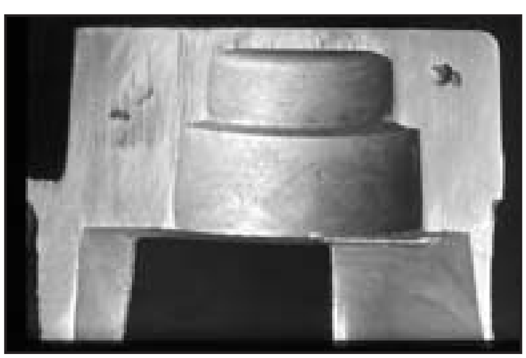

Figure 3. *Shrinkage porosity - lack of feeding-casting.*

on strength will depend as much on the distribution of porosity as on its amount. It should always be remembered that the “book” strength values quoted for the alloys were obtained on specimens containing typical amounts of porosity.

Increasing the metal pressure and ensuring that the gate is thick enough to remain active during solidification can reduce the amount of shrinkage porosity. The plunger must not creep so much that it touches the bottom of the gooseneck, which can result in a lack of pressure being exerted on the metal. The packing time must be long enough to allow full solidification otherwise metal will be sucked out of the cavity as the plunger returns. Local cooling may eliminate hot spots and so prevent the formation of isolated areas of liquid metal which on freezing will form pores.

The interdendritic type of porosity can give rise to leakage in components which are required to be pressure tight. The longer the freezing range of the alloy the more likely leakage is to occur. Casting with a low die temperature thickens the casting skin and can reduce the incidence of leakage. However, this technique may be limited by the need to have a sufficiently high die temperature to produce a satisfactory surface appearance. The usual range of die face temperature is 170°C – 240°C.

Gas Porosity

As the die fills rapidly, large amounts of gas can be trapped. Following solidification under high pressure the gas occurs as quasi-spherical bubbles, typically at the centreline (figure 4). Gas and shrinkage porosity can occur together in which case the presence of the gas tends to round out the shrinkage porosity.

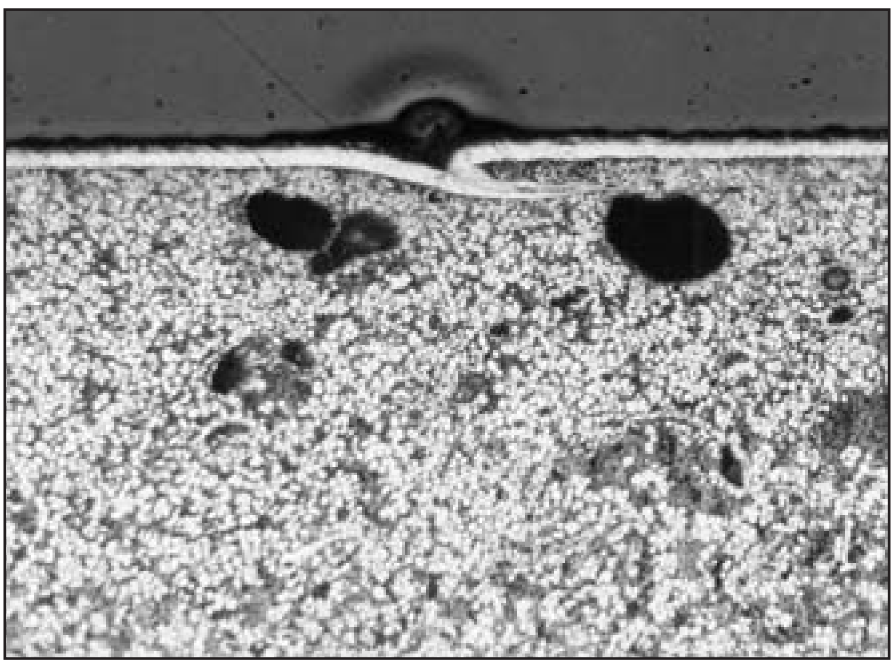

Figure 4. *Gas porosity - air entrapment-casting*

Gas porosity gives rise to the same defects as shrinkage porosity, although leakage is less likely to occur as gas pores are seldom interlinked. In addition, gas porosity is the direct cause of blistering in castings. The high gas pressure in the pore can blow out the surrounding metal skin if the alloy is weak, ie through being at elevated temperatures. Increasing the cooling time and/or reducing the die temperature can prevent the incidence of blistering immediately after ejection.

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Ideally the amount of gas trapped in the cavity needs to be reduced. This is done by using a maximum possible first stage stroke and the longest possible fill time (bearing in mind the conflicting need for short fill times to attain good surface appearance). Vents should be maximised and correctly positioned. Keeping die spray to a minimum is beneficial. Porosity is generally less of a problem, and certainly causes less blistering, when it is present as many small pores rather than a few big ones. Small pores are encouraged by using high metal speeds; gate speeds of 40m/s should be the aim. Vacuum die casting will eliminate this type of porosity.

Microporosity

In addition to the visible porosity there will also be porosity of a size that can only be seen under the microscope. This microporosity, provided it is absent from the casting skin (as it often is), has no detrimental effect unless it is subsequently exposed by polishing operations prior to surface coating.

Tears and Cracks

Hot tears, as the name implies, occur at temperatures around the solidification range. The crack is formed by failure of the casting under high strain, low stress deformation and typically shows an irregular path (figure 5). This is in contrast to the generally much straighter cracks which can form at lower temperatures under conditions of high stress and low strain. There is also a difference in the appearance of the crack faces in these two types of defect.

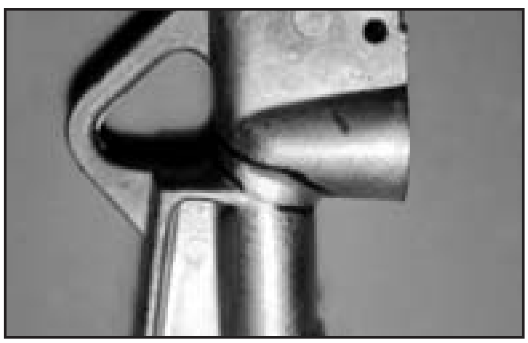

Figure 5. *Hot tearing - composition, hot spots-casting.*

Hot tearing is largely a consequence of the component shape. It occurs when solidification shrinkage is constrained to a small area, especially where that area is also a hot spot. ZA-27 and Acuzinc are more prone to this defect than the other alloys unless those alloys are below specification for aluminium or contain excess magnesium. In general, hot tearing is not influenced by casting parameters except for die temperature distribution. Cooling the hot spots in the die can alleviate the problem.

Cracking occurs on ejection if excessive forces are developed as a result of the casting jamming in the die. This occurrence is often the result of toolmaking errors that have led to undercutting, insufficient draft or flash. Extending the cooling time so that the casting is stronger and thus better able to withstand the ejection forces may prevent cracking. However, where the force arises because the casting has shrunk hard onto the die, long cooling times will be counterproductive and ejecting sooner may be helpful.

Inclusions

This is far less of a problem in zinc alloys than in those that are more strongly oxide film formers. Indeed, it is usually only pick-up of iron intermetallics produced by poor melt control which causes any problems

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in practice. The metal level in the pot must not be allowed to fall to such an extent that sub-surface metal enters the gooseneck.

Surface Defects

Cold Laps

This defect (also known as flowmarks or cold flow) occurs when streams of metal that have pre-solidified in contact with the die are not remelted back into the bulk of the casting by the arrival of further metal. The surface appearance is an irregular groove, giving a fish scale effect, whose depth depends on the severity of the lap (figure 6). The cross-section shows the characteristic feature of a cold lap that is the extent by which the surface crack extends horizontally and forms a subsurface discontinuity (figure 7).

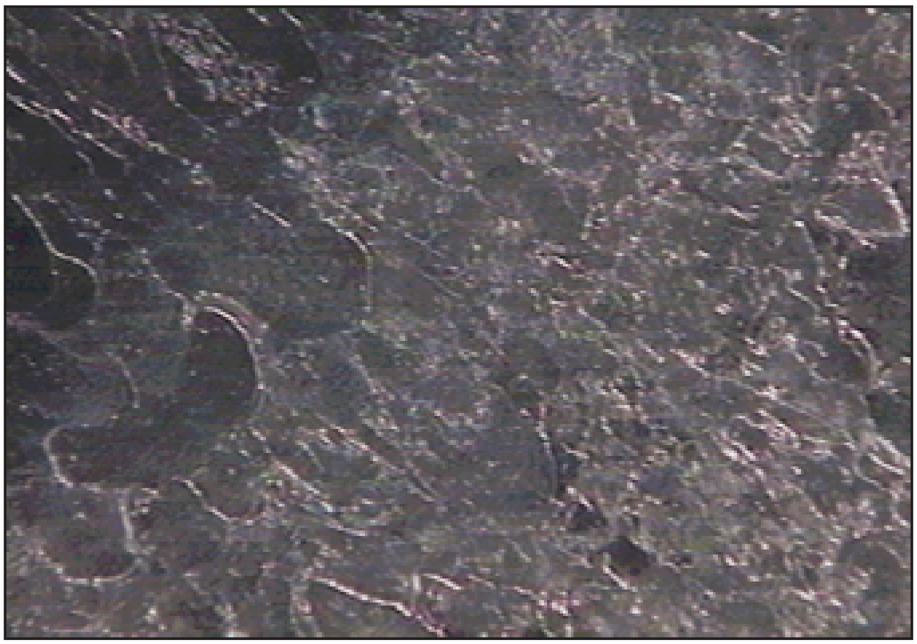

Figure 6. *Cold flow-fill time, die temperature-casting.*

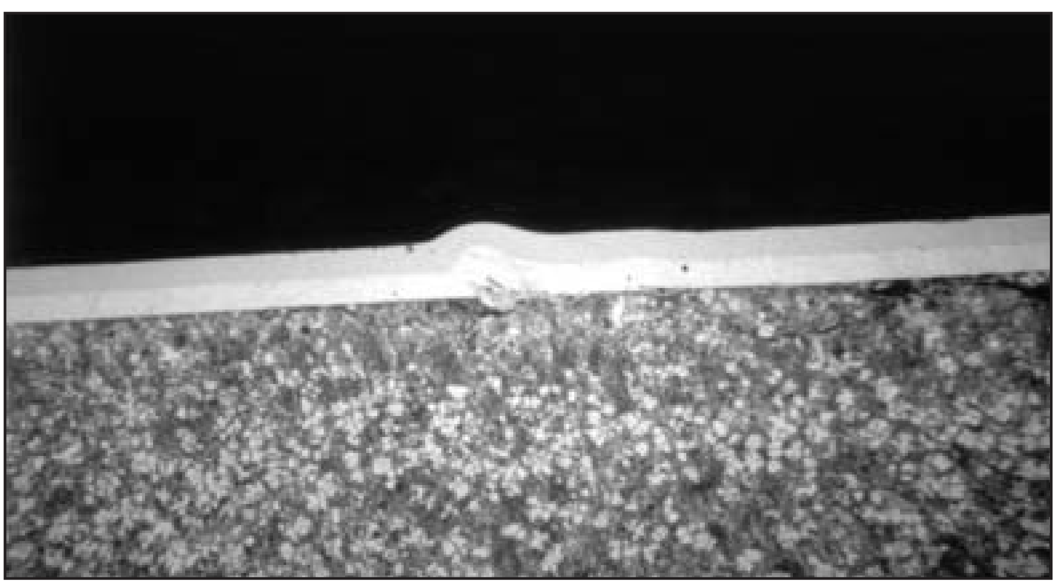

Figure 7. *Cold flow section with plating-casting.*

Cold laps spoil the appearance of castings and cause problems with subsequent finishing operations, particularly electroplating, which lead to coating failure. If severe, laps can reduce the ductility of the casting.

The main casting parameters effecting the formation of cold laps are the cavity fill time and the die temperature. Less important factors are flow pattern, flow distance, metal speed, die surface, and metal temperature. The thickness of the casting is important. Laps are more likely to occur in thin section castings.

The relationship of surface appearance to wall thickness, die temperature and fill time has been established. The Surface Predictor (figure 8) can be used to specify the combination of maximum cavity fill time and the minimum die temperature that will produce an electro-platable surface. Somewhat longer fill times or lower die temperatures are allowable if the part is to be painted. A textured surface on the die can extend the maximum fill time by 50%.

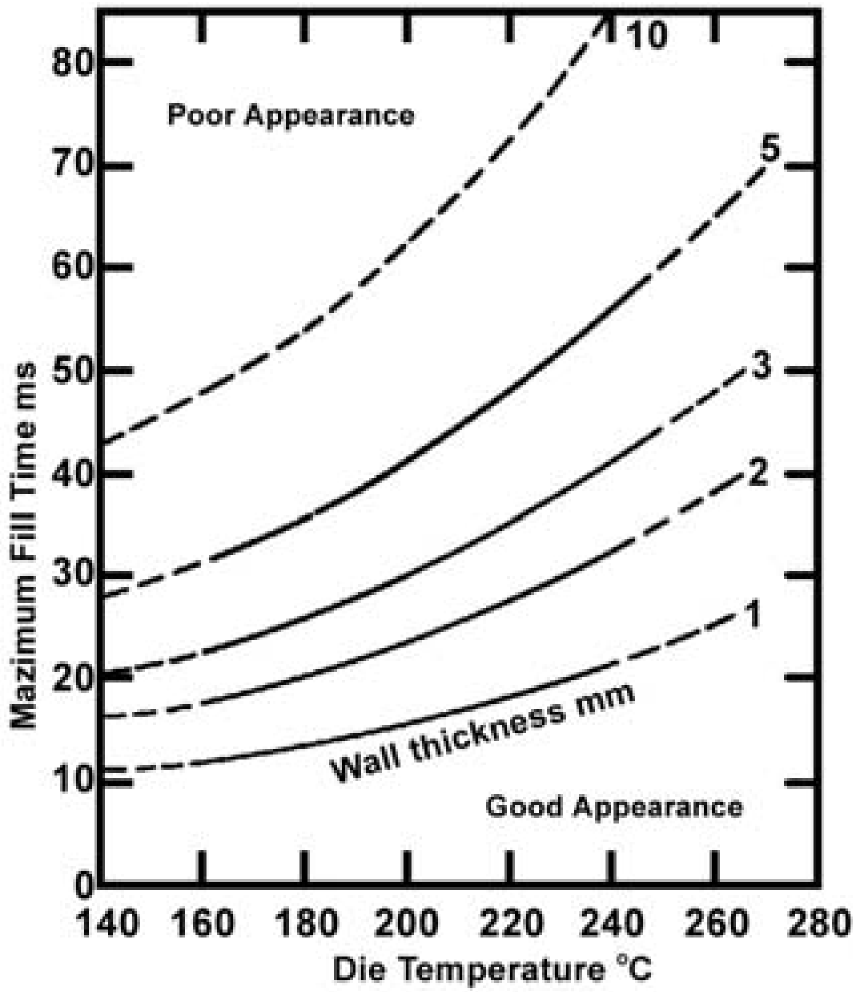

Figure 8. *Surface finish predictor.*

Sometimes laps will appear even though the die is hot and the cavity fill time short. When this occurs they are usually associated with a swirl flow pattern that has trapped gas. The back pressure exerted by the gas at the end of cavity fill slows the encircling metal steams and hence produces the conditions necessary for local lap formation. In this case, it will be necessary to reduce the air entrapped in the die (see section on porosity) or modify the filling pattern in order to prevent the formation of such laps.

Lamination

Laminations are overlapping sheets of metal extending over a wider area and in a more uniform manner than cold laps. They can arise when there are problems with the machine injection system that results in the die filling in a series of pulses. A lamination will also form if the first stage stroke is too long with the result that the first metal entering the cavity is moving slowly and freezes off.

Misrun

If the die is too cold and the fill time far too long, a complete casting will not be made. The metal will completely solidify before the cavity is filled and a misrun will result (figure 9). Small areas of incomplete make up, eg on the ends of fins or at the centre of swirls, may be caused by entrapped gas preventing metal completely filling the cavity. If the shot capacity of the machine is exceeded then the "short shot" will cause a misrun.

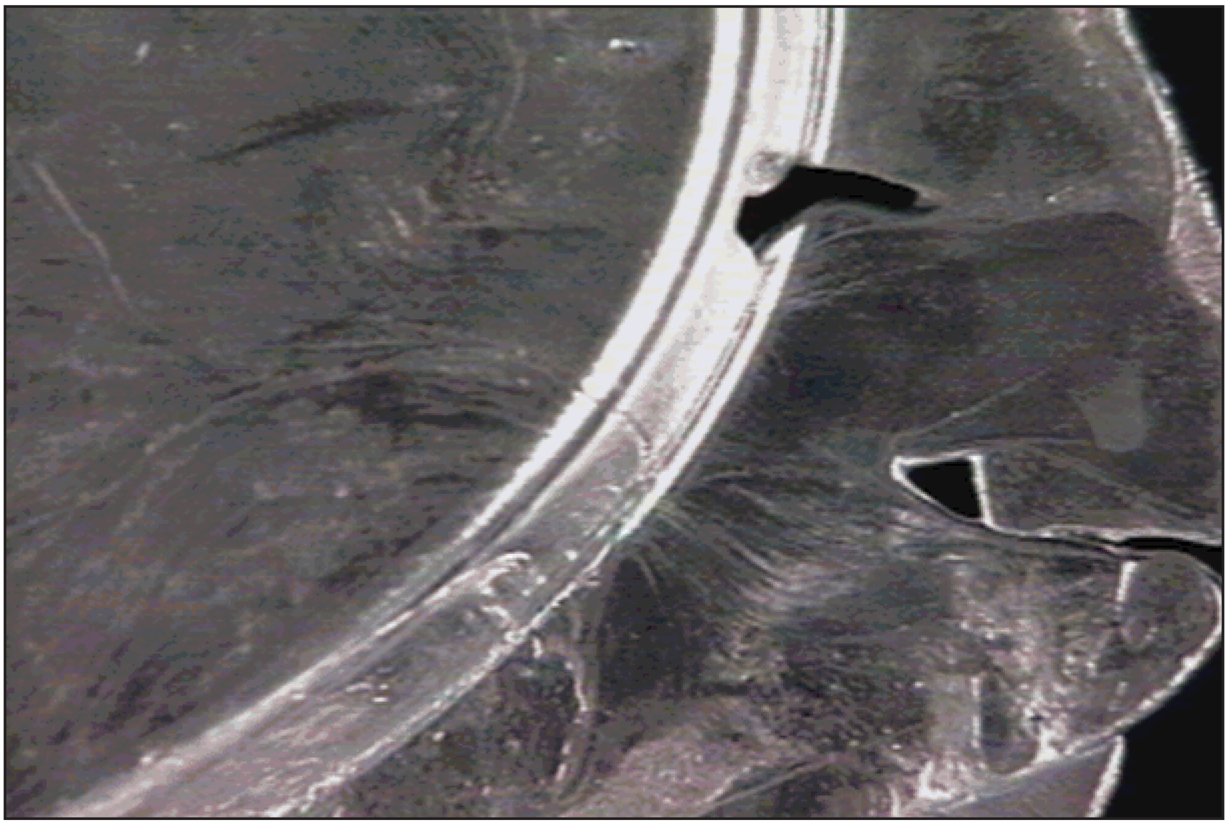

Figure 9. *Misrun-fill time, die temperature-casting.*

Shot or Spatter

Like laps these are the result of pre-solidification but appearance and cause are different. The defect can be purely surface, where it produces a rough texture, or can be imbedded as an "alloy inclusion" (figure 10). The "shots" are globules of alloy that have been sprayed out of the main metal stream and have not been subsequently adsorbed. The spray can arise from the pulse as the first metal flows through the gate or can be eddies curling off the edge of the metal stream. This is why spatter usually occurs close to the gate. Sometimes the spatter is so loosely bound to the casting that some will be left behind on ejection. This material will then form "inclusions" in the next casting.

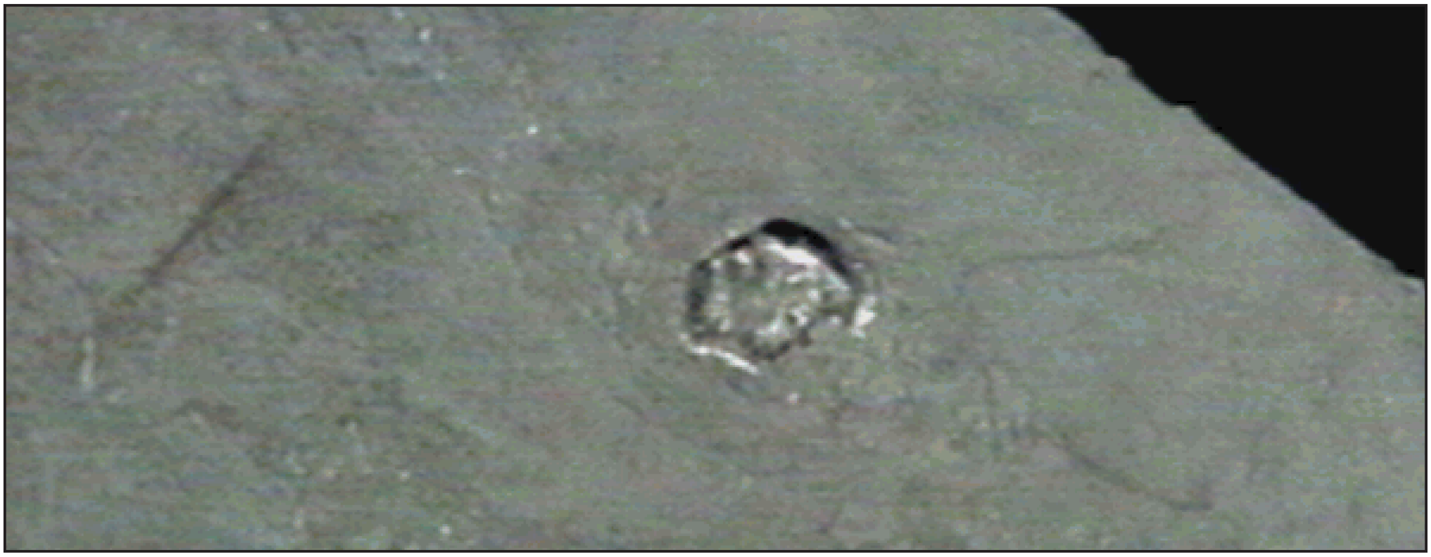

Figure 10. *Shot-presolidification-casting.*

Raising the die temperature should improve matters but the main remedy will be to modify the gate so that a more solid front fill is achieved.

These depressions in the casting surface are less common in zinc alloy than some other metals and much less of a problem than in plastic mouldings. The cause is the same solidification shrinkage that is the driving force for porosity formation. A local heavy section displays a surface sink rather than an internal pore when the temperature distribution is such that the heat centre is close to one surface. The final shrinkage then draws down the weak solid casting skin to form a depression (figure 11).

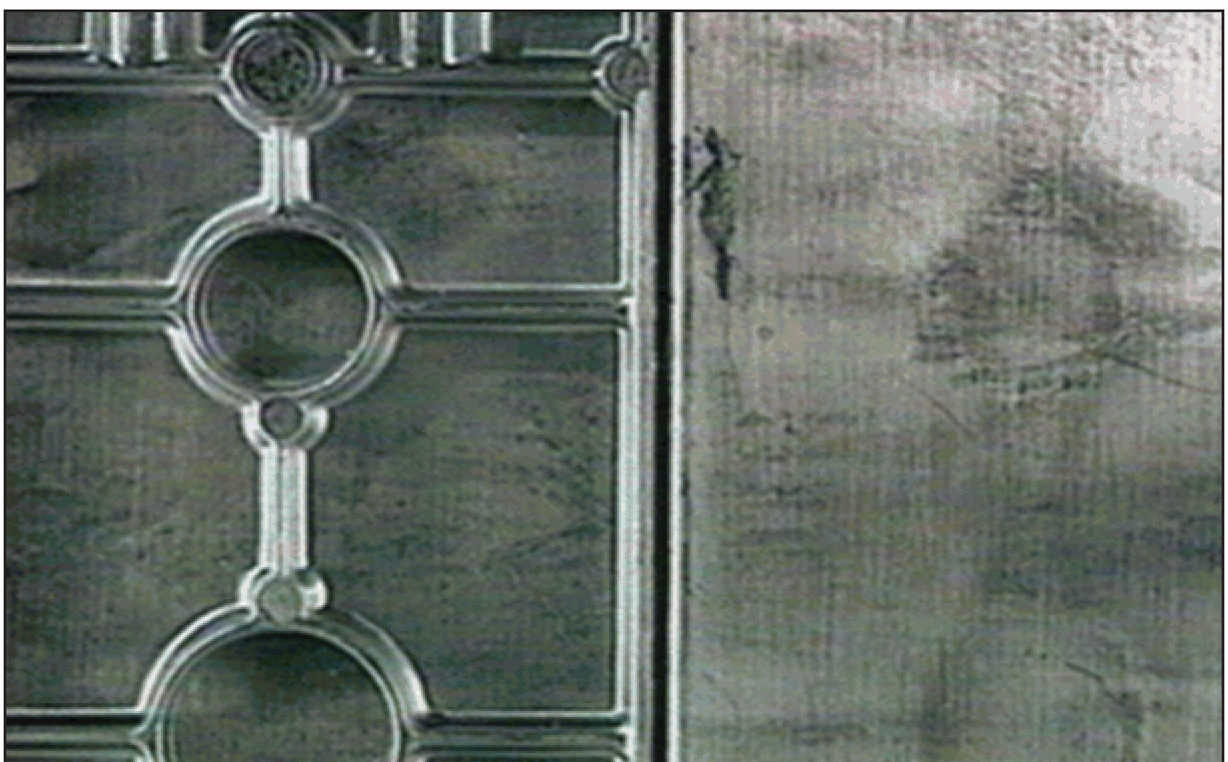

Figure 11. *Sink hotspot-casting.*

In alloys such as ZA-27 the appearance can be different. Here the defect is over a broader area and appears frosty. The long freezing range has modified the behaviour so that rather than a definite sink the shrinkage has drained the surface of eutectic liquid and left it rough and semi-porous.

The process remedies are the same as those given under shrinkage porosity. A redesign of the casting to reduce the hot spot should be carried out if this is possible.

Lakes

A lake is broad step in the casting surface with a step height of only 5 to 30 micrometers. It becomes very noticeable on components that are subsequently polished and plated where it produces an unsatisfactory ripple effect (figure 12).

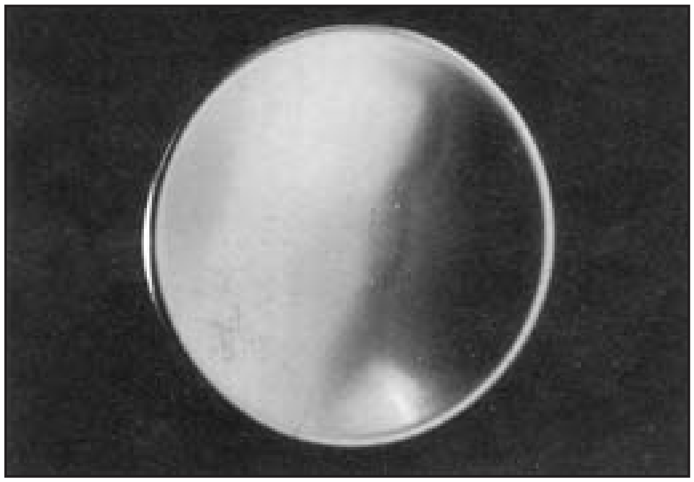

Figure 12. *Lake-temperature distribution-casting.*

Despite intensive investigation, the cause, and hence the remedy remains elusive. There is evidence that the term "lake" may be given to two defects of the same appearance

but different cause. When sectioned, some lakes show a different microstructure under the lake than in the bulk of the casting or the surrounding surface. Lakes of this type seem to be associated with early local solidification and the remedies taken for cold laps may be beneficial.

Other lakes, however, show no microstructural change. Additionally on thin castings, it is not uncommon for the defect to be through thickness, ie there is a depression on one side and a raised area on the other. In effect the casting has kinked by a few tens of microns. This indicates that the lake has formed when the casting was solid and it is tempting to speculate about restrained shrinkage producing an "oil can" distortion.

It is fairly clear that the defect is heat related and probably reflects temperature gradients within the tool.

Blisters

Cutting open these smooth surface protuberances reveals their hollow centre. Blisters are caused by expansion of the high pressure gas trapped in gas pores swelling the surface skin of the casting (figure 13). The blisters form when the alloy is too weak to contain the forces generated by the internal gas, ie when the

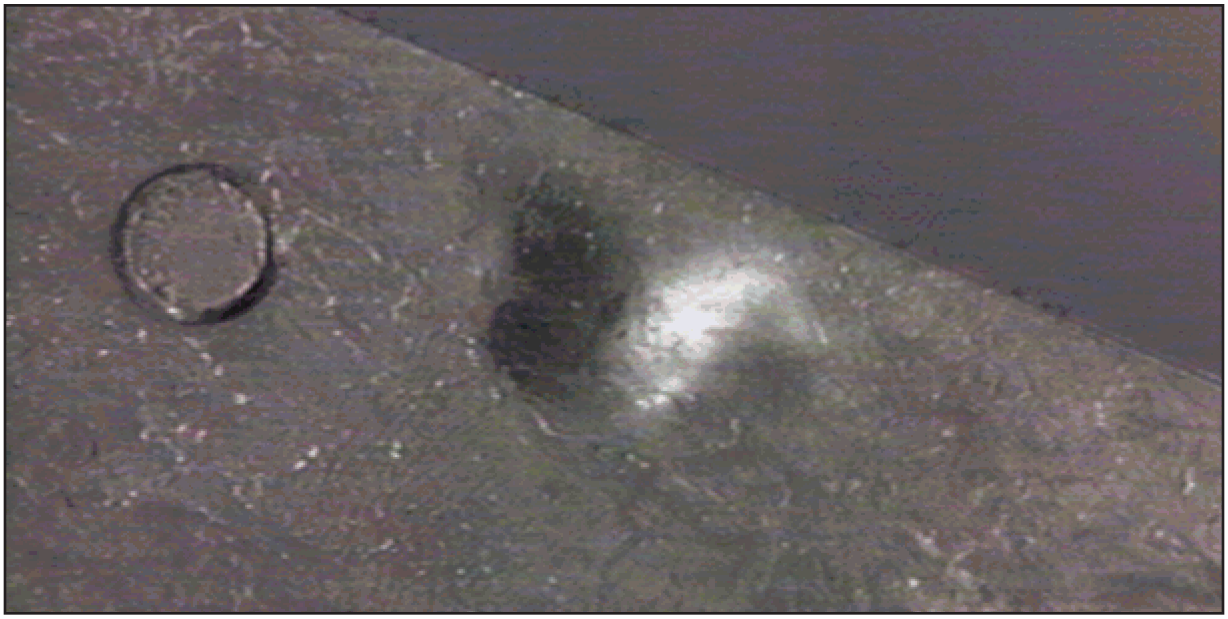

Figure 13. *Blister - air entrapment - ejection, painting.*

casting is too hot. Blistering is prevented by reducing the temperature of the casting at ejection. This is achieved by increasing the die cooling and/or increasing the die cooling time. Blistering will be alleviated by reducing the amount of trapped air (see section on gas porosity) and by using a high gate speed in order to refine the gas pore size.

Cracks

Surface cracks can be due to two different causes. The first type, usually seen at section changes, are hot tears where the high local strain caused by restricting the shrinkage close to the melting temperature has resulted in an intergranular fracture. The second type is due to the casting sticking in the die that leads to high stresses being developed during ejection. These cracks are generally less intergranular and straighter than those due to hot tears.

Hot tearing is more marked in long freezing range alloys, for example ZA-27, and is largely due to the component shape. Local cooling on the trouble spot may be beneficial. (See ingot section for more details).

Ejection cracking should first be tackled by eliminating any die problems such as undercuts, insufficient taper and rough surface. The casting will be stronger, and hence better able to resist the ejection forces if it is cooler, so lowering the die temperature and increasing the cooling time would be beneficial. However, if the sticking is being caused by the casting shrinking onto the die, eg a bore onto the core pin, then earlier ejection which will reduce the amount of shrinkage may be helpful. The die spray must adequately cover the die face in order to act as a satisfactory parting agent.

Drag Marks

Scores in the line of draw are caused by rubbing between the casting and the die as the component is ejected (figure 14). Insufficient draft, undercuts, and surface roughness will lead to drag marks as will inadequate die spray. It is difficult to avoid some scuffing where the casting is shrinking tightly onto the

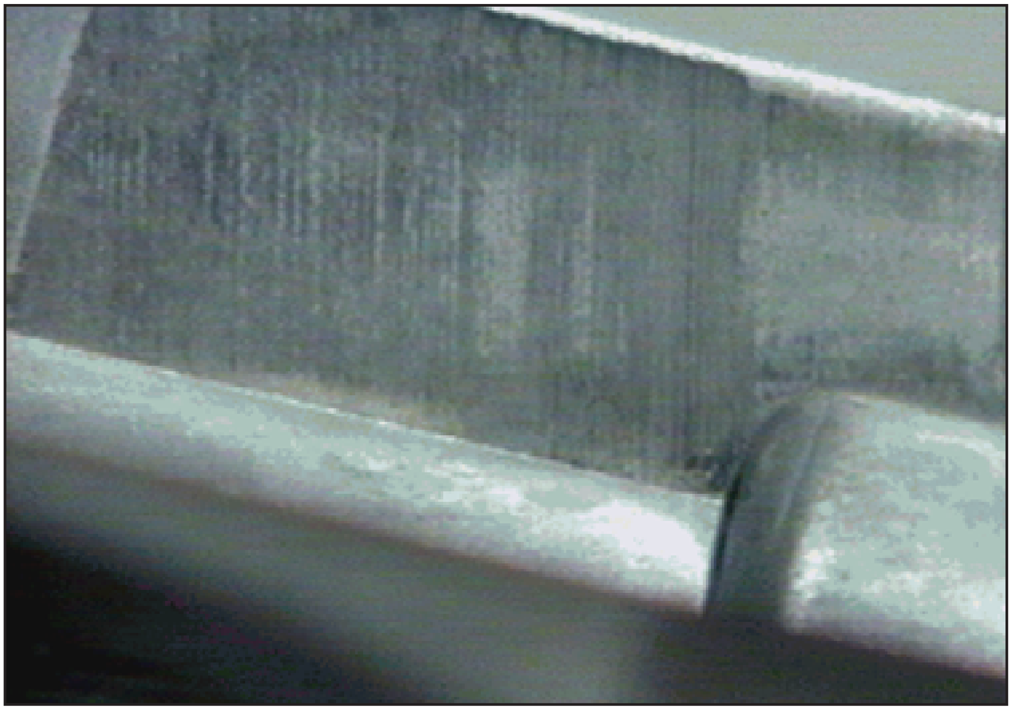

Figure 14. Drag-die makeing, soldering-ejection.

component. In these areas, maximum allowable taper is needed and optimisation of the time (temperature) at which to eject the casting.

Distortion

Bent castings, indentation or piercing by ejector pins, arise when the casting is too weak to withstand the ejection forces (figure 15). The die should first be checked for undercuts, insufficient draft and rough surface. The problem may then be controlled by lowering the temperature at which the casting is ejected. This is achieved by lowering the die temperature and/or increasing the die cooling time.

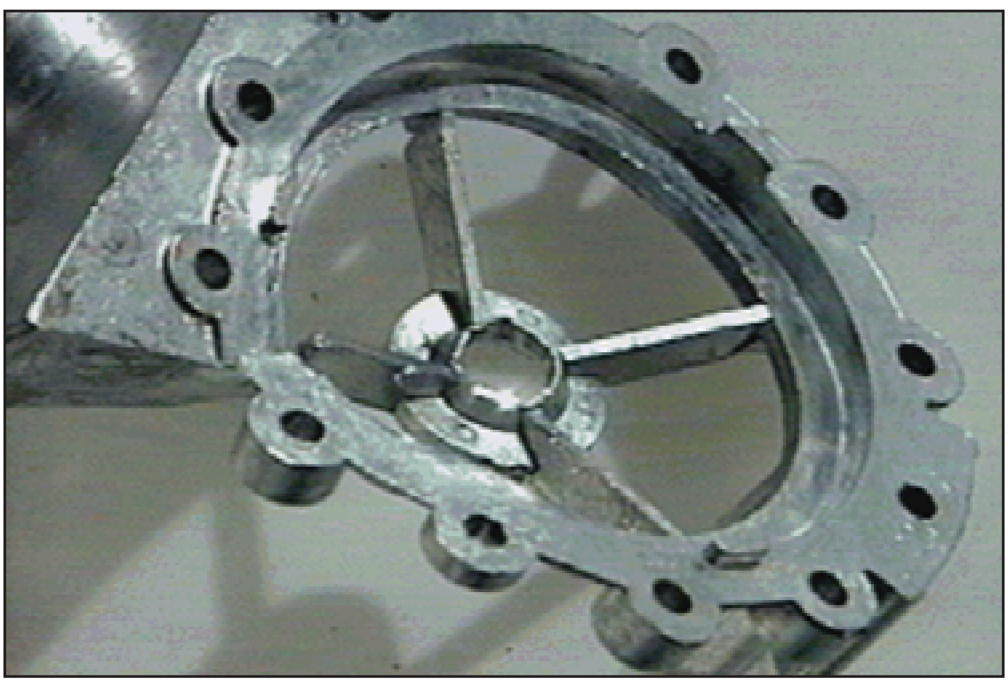

Figure 15. Distortion-die making, temperature-ejection.

Erosion

Erosion produces wear and cavities in the die surface which can cause marks on the casting and ejection problems. It also reduces the life of the die. The molten alloy physically wears away the die at places where the metal stream hits the die at high speed. Wear may also occur at points where the high speed metal eddies and produces hydraulic cavitation. In both cases reducing the metal speed will reduce the amount of erosion. Erosion is also reduced by lowering the die temperature. It is more likely to occur in dies that are tempered to the soft side of the hardness range.

Heat Checking

A crazy paving pattern of fins on the casting surface is due to the die surface breaking up (heat checking). The cause is the surface stress induced by the temperature cycle that occurs as each casting is made. The severity of the stress depends on the melting temperature of the alloy. As zinc alloys have low melting ranges, this defect is rare and is only seen in dies which have produced millions of castings.

Soldering

This is the build up on the die surface of a layer of alloy that is both physically and chemically adhering. The casting is marked where the stuck skin is torn away on ejection and the undercut produced by the build up also leads to scoring of the casting. Soldering is more likely when gate speeds are high and the die temperature is high. Die spray must be adequate in order to produce a protective layer on the steel surface. Build up due to solder is difficult to remove from the die. This distinguishes it from build up due to excess die spray which usually can be wiped off.

Flash

When metal penetrates between the mating faces of the die parts and the die halves, thin layers of extraneous material are left on the casting (figure 16). To prevent this the dies must be strongly built and perfectly

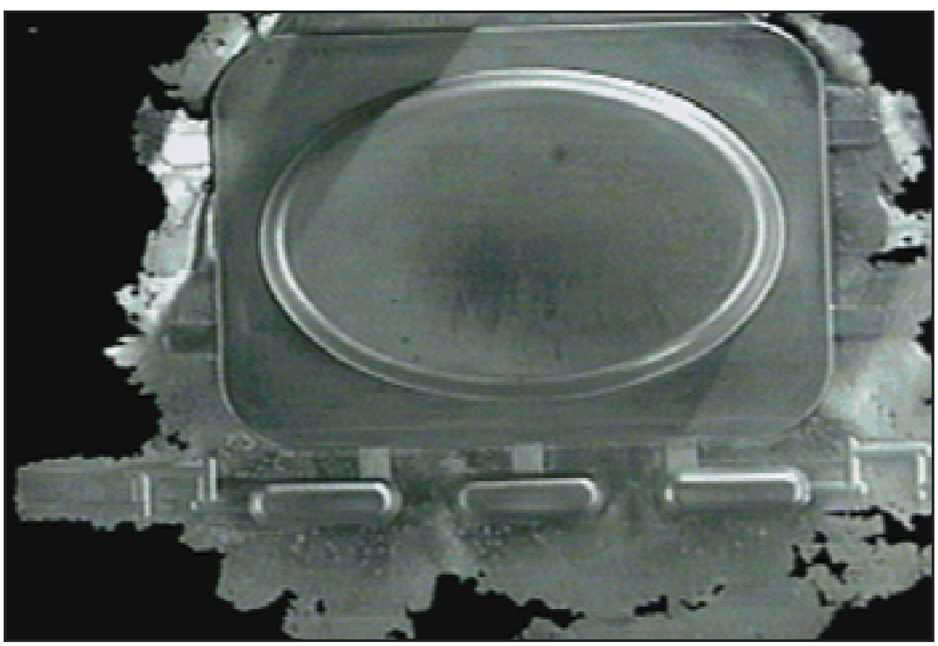

Figure 16. *Flash-pressure-casting.*

shut out. Even then thermal deflections may lead to gaps opening at operating temperature. If the machine locking force is inadequate for the size of casting being made, the dies will part and extensive areas of flash will be formed. Reducing the metal pressure will reduce the likelihood of the dies flashing. Also increasing the fill time, and thus reducing the temperature of the metal by the time it reaches the split line, will reduce penetration between mating faces.

Dimensional Consistency

The whole issue of dimensional tolerances is dealt with at length in another chapter of this manual. It is mentioned here because non-conformance can be considered a casting defect.

The reproducibility of an as-cast dimension shot after shot, is almost exclusively a function of temperature consistency. The factor that has the greatest effect is the temperature of the casting at the moment it is ejected from the die. Stabilising this temperature will improve dimensional reproducibility and aid the holding of close tolerances.

Because of metallurgical ageing effects, there will be slight shrinkage with time after casting. The amount is small and reproducible and is only an issue in components specified to the very tightest tolerances. A low temperature heat treatment, typically a few hours at 95°C, can be used to stabilise the casting if necessary.

Trimming and Dressing

General problems in this area of the production operation are unacceptable change of contour due to over-removal of metal and distortion due to rough handling or alignment problems.

Break-off Defects

The thin gates possible in zinc alloy casting make break-off rather than press trimming an option in many cases. Break-off may be manual or mechanical in scroll or tumbler machines. A clean break depends on the shape and thickness of the gate.

Earring

Slightly curved gates can be broken but tend to leave "ears" on the casting when tapered gates are being used. Depending on the design and direction of bending even on a straight gate the land may be left proud of the casting.

Break in

Here the gate shape and direction of bending has led to the fracture entering the casting, thus leaving an undercut in the casting.

Gate line Porosity

Even when the gate breaks cleanly a witness is left on the casting. The metal exposed is different to the surrounding casting skin; it is typical of the interior of the casting and can thus contain porosity (figure 17). The thicker the gate the more likely it is for this porosity to be visible. The amount of gate line poros-

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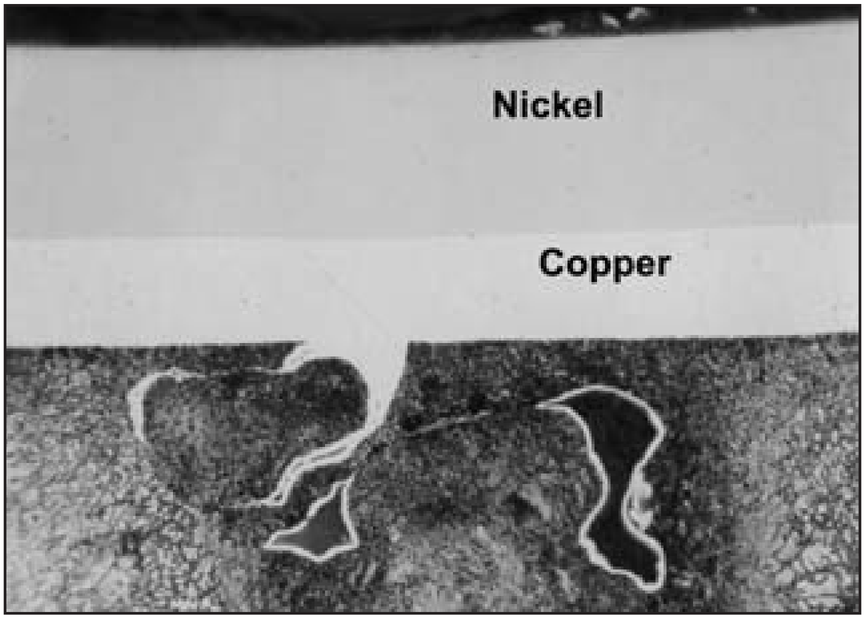


Figure 17. Gate line porosity-design-trimming.

ity will be influenced by the factors covered in the Porosity section of this chapter. Even when not visible the exposed microporosity may cause a problem after coating.

Press Trim Defects

Scoring

Incorrect seating of the component and/or incorrect die alignment and clearances can lead to the trim die shaving the side of the casting.

Folding

When flash is thin and only extends a short distance, the ductility of the alloy is such that the flash may bend rather than be cut. The result is a thin fold of metal on the surface of the component. Where this is a problem it may be better to deliberately flash across, rather than unsuccessfully shut out, so that there is a definite thickness for the trim tool to cut.

Finishing Defects

Excessive removal of the surface will expose microporosity. This may not be visible but will lead to problems if the casting is subsequently coated.

Barrelling/Vibropolishing Defects

Scaling

Excessive treatment of heavily lapped castings can lead to the laps lifting or becoming completely detached (figure 18).

Polishing Defects

Excessive metal removal will expose microporosity. The appearance of small bumps and comet tails are due to hard particles in the casting arising from metal contamination. As with barrelling and vibropolishing,

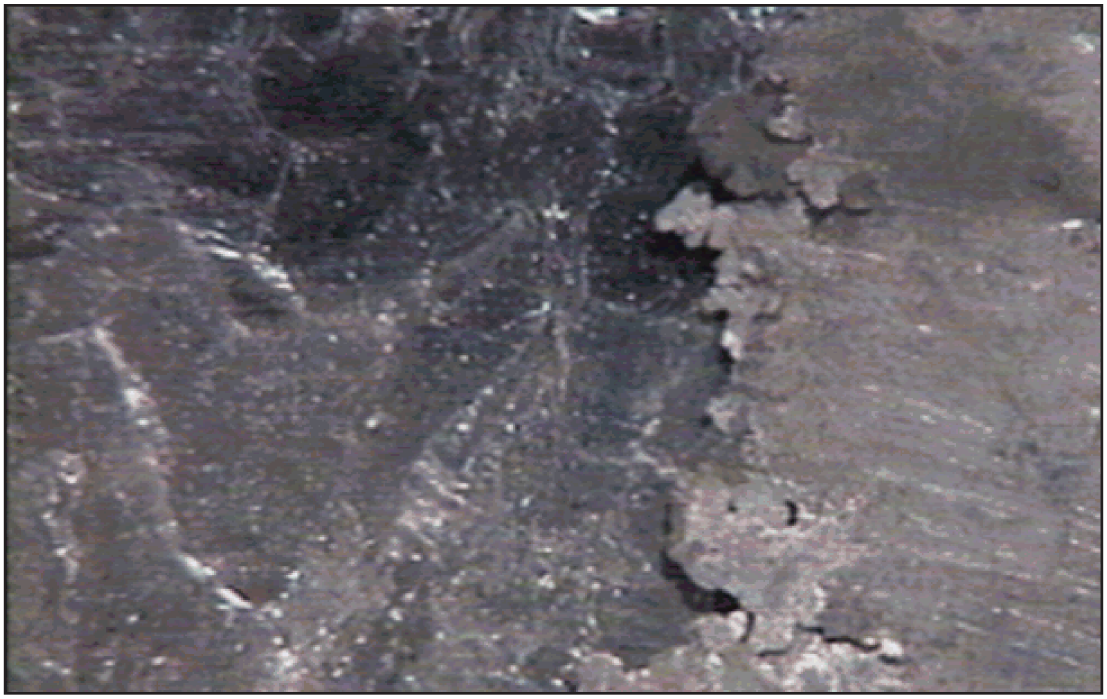


Figure 18. Scaling-cold flow-dressing.

the burnishing action only hides surface defects, such as laps. The underlying discontinuity is still present and can cause problems later.

Machining and Assembly

Tool Wear

Rapid wear of cutting tools may be due to hard particles in the alloy arising from contamination of the melt. The causes and control measures to avoid this are covered in the Ingot section. Wear and breakage can also be caused by the tools penetrating large gas or shrinkage pores. The avoidance of porosity is dealt with in the Casting section.

Exposed Porosity

Removal of the sound surface skin may expose porosity on machined faces, eg on flanges or down bores. The control of porosity is dealt with in the Casting section.

Fracture

Riveting and bending operations are frequently used to assemble zinc alloy castings. If the as-cast rivets and lugs are not well made, fracture of these features may occur. The surfaces need to be free of excessive laps and cracks (see Casting section). The ageing process that occurs after casting affects the ductility. It is at a minimum about three weeks after casting. The ductility of the alloy is much increased by deforming at moderately elevated temperatures.

Coating

In this section defects that arise during coating, and to the coating in service, are examined. Only those defects caused by faults in the casting are covered. A more complete coverage, which includes defects in the coat itself, is given in the booklets “Plating of Zinc Diecastings” and “Powder Coating of Zinc Diecastings” which were published by the Zinc Development Association, London, UK.

Distortion

The strength of zinc alloy decreases with temperature so at paint stove temperatures it is fairly weak and even plating bath temperature has some effect. Thus if the castings are poorly supported or the jigs exert too high a spring force, the castings will be deformed.

Warping may also occur due to the stress relief of the casting. The rapid cooling during casting can lock in stresses caused by differential shrinkage. The level of stress depends largely on the component shape.

Irregular Surface

The fish scale appearance of cold laps will show through the plating layer and, if severe, may also show through the thicker paint coat. The boundaries of lakes will show as a ripple mark on the plated or painted surface. The causes and remedies of these defects are given in the Casting section.

Plating Defects

Blisters

Blisters in the electroplate which are the fault of the casting (blisters and other defects can also be due to plating process problems), are due to the trapping of soil, gas and plating solutions in surface defects. The evolution of gas beneath the impermeable plating will cause it to blister and possibly crack. The expansion caused by corrosion products being formed by reaction between the casting and trapped corrosive solutions will have a similar effect. If the entrapment is due to cold laps, the casting surface as well as the plate may lift. Note that folds due to flash being bent onto the surface will cause similar problems to laps. If put into service, the damage done to the plated layer will lead to corrosion. (figures 7, 19)

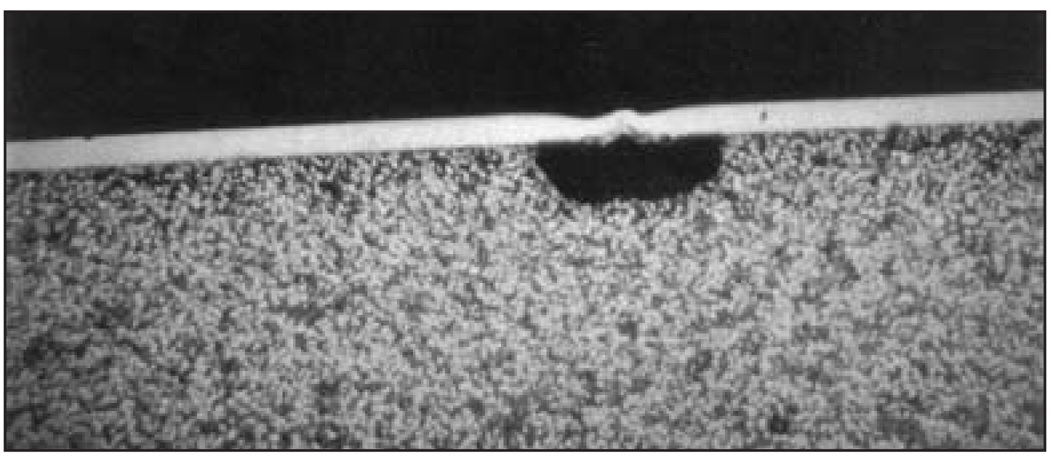


Figure 19. *Corrosion-porosity-plating.*

Castings which have a surface containing cold laps or one in which gross porosity or micro-porosity has been exposed, are likely to produce blisters in the plated coat. Details on these defects are given in the Casting and Dressing sections.

Click Here to Close This Chapter

Paint Defects

Blisters

There are two types of blisters that can appear on the painted surface of a casting. It is important to distinguish between them as the remedial measures required are different.

Blisters that generally are of reasonable size and possibly appear on opposite sides of the casting are caused by gas porosity within the casting (figure 13). This can be confirmed by scraping off the paint coat or cutting the blister open. It is a gas blister if the defect is in the casting and not the paint. The defect occurs because at paint stove temperature the zinc alloy is weak and the high pressure gas inside the pores cause the casting to swell.

Stove temperature is critical and if the process allows a choice of conditions, the option of stoving for longer but at a lower temperature should be taken. Castings that are to be high temperature baked (200°C) have to contain the minimum amount of trapped gas and it needs to be finely dispersed (see Casting section).

Smaller blisters are due to gas evolving from the casting surface and becoming trapped in the paint film. Sometimes the gas does escape but the solidifying paint is already too set to reform a smooth surface - the result is a blister looking like a miniature volcano (figure 20). To prevent these defects the casting needs to be free of surface discontinuities that will trap gas and soil, eg cold laps, folds and exposed porosity. Baking before applying the organic coat will outgas the casting and alleviate the problem.

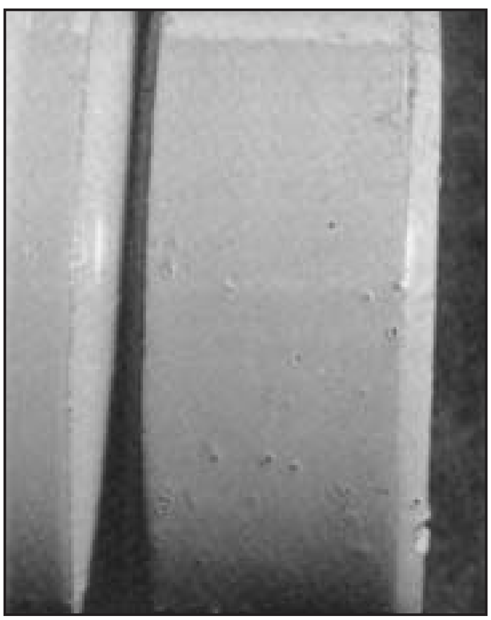


Figure 20. *Cissing-cold flow-painting.*

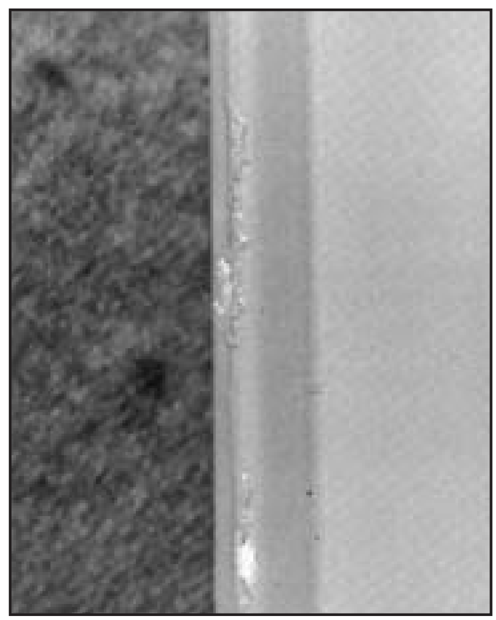


Figure 21. *Chipping-folding-painting.*

Chipped Paint

Occasionally the chipping off of paint can be associated with a casting defect as well as post coating mis-handling. If a fold (ie bent over flash) is covered with paint and then subjected to impact, it may break off and so reveal the underlying uncoated surface (figure 21).

Handling, Storage and Packing

Poor handling can cause surface damage or distortion of the casting. In multi-cavity tools it can be useful to cast ties between flimsy components to provide support. The surface damage that can be tolerated will depend on the quality requirement and coating that will be applied.

When bare castings are to be stored for any length of time, it is essential that they are dry. Damp conditions will lead to the formation of white rust and superficial corrosion. If there has been degradation of the die spray or quench water with the formation of acidic compounds, a more severe corrosion may occur. Castings should be plated or painted as soon as possible after casting and polishing in order to minimise the possibility of surface contamination.

Castings need to be packed in dry materials, in particular, wet cardboard produces acids which will attack and blacken zinc castings.

Defect Identification and Correction

Appearance is the main means of identifying defects but it is also useful to establish the point in the manufacturing process at which the defect first appears. This will, for example, distinguish between dragging on ejection and scoring by the trim press.

In Chart 1 photographs of the main defects are shown together with their identity, cause and the associated process operation. Chart 2 lists the process operations and indicates the defects which can arise in each operation.

Over the years there have been a number of publications listing defects (and the means of correction) and various systems of defect classifications have been devised. Among the more recent are:

Zinc Die Casting Defects Manual . . . . Cominco, Canada

Zincaster (as part of training CD ROM) . . . . IZA, Belgium

Alexsys . . . . Metallguss Aalen, German

Defect Classification System . . . . Eastern Alloys

Diadem . . . . CTIF, France

Die Casting Defects . . . . NADCA, USA

In addition the ZDA (UK) booklets "Plating of Zinc Castings" and "Powder Coating of Zinc Castings" deal specifically with the problems that arise during surface coating.

An early fault-finding scheme was devised by BNF in the UK. This is now out-of-print so for convenience it has been reproduced below. It summarises the defect correction procedures which have been outlined in the various sections of this chapter.

Appendix A

Summary of Fault Correction Procedures

1. Surface Finish

(a) Cold Shuts. Misruns or Incomplete Filling of the Cavity

(i) Increase die surface temperature at injection

1. Increase shot rate by reducing the die open time
2. Reduce cooling in the die
3.* Insulate insert from the bolster
4.* Introduce heating in the die

(ii) Increase rate of filling cavity

1. Open up speed control valve
2. Increase injection pressure
3.* Increase gate size

(iii) Increase volume of over-flow wells

(b) Heat Waves

(i) Reduce Injection speed

(ii) Reduce die temperature

1. Increase local cooling in the die
2. Reduce casting rate
3. Check condition of cooling water channels and inlet temperature of water

(c) Blisters

(i) Reduce temperature of casting at die open

1. Increase die closed time
2.* Use DT/CT controller to open die when casting is at the correct temperature

(ii) Reduce entrapped gases

1. Reduce injection speed
2. Use 2-stage injection
3. Use minimum die lubricant
4. Reconsider type of die lubricant
5.* Improve venting in the die

(d) Sinks

(i) Increase injection pressure

(ii) Increase local cooling

(e) Lamination

(i) Arrange for injection change-over to occure before metal reaches the gates

(ii) Eliminate jerky injection. Check:

1. Accumulator pressure
2. Conditions of sleeve and plunger

(iii) Increase die temperature at injection

(f) Blisters

Click Here to Close This Chapter

(i) Reduce injection speed

(ii) Reduce die temperature

1. Increase local cooling
2. Reduce casting rate
3.* Check condition of cooling water channels and inlet temperature of water

(iii) Increase gate size

(g) Dragging

(i) Open die at optimum temperature - use the DT/CT controller

(ii) Reconsider type and quantity of die lubricant used

(iii) Improve lubrication

(iv) Check die alignment and whether fixed half is bending from nozzle load as die opens

(v) Check surface finish and hardness of the die

(vi)* Increase draft

(h) Die Erosion

(i) Reduce injection speed

(ii)* Check hardness of die

(iii) Nitride cavity surface

2. Soundness

(a) Increase Pressure Transmitted during Solidification

(i) Increase pressure in the injection cylinder

(ii) Reduce size of plunger

(iii) Increase cooling on heavy sections if problem in this region

(iv)* Reduce heavy flashing

(v) Increase gate thickness if small in relation to casting

(b) Reduce the Entrapped Gases

(i) Reduce filling speed

(ii) Use 2-stage injection

(iii) Use the minimum die lubricant and lubricate every shot

(iv) Reconsider type of lubricant

(v)* Improve venting

3. Dimensional Reproducibility

Improve consistency of casting operation by running machine automatically and/or use the BNF DT/CT controller

If casting dimension is: -

(a) too big, - reduce die closed time or increase temperature setting on the cycle/time controller

(b) too small, - increase die closed time or reduce temperature setting on the cycle/time controller

4. Metal Dribble From Sprue Hole

(a) Use plunger overlap

(b) Check metal level in holding pot

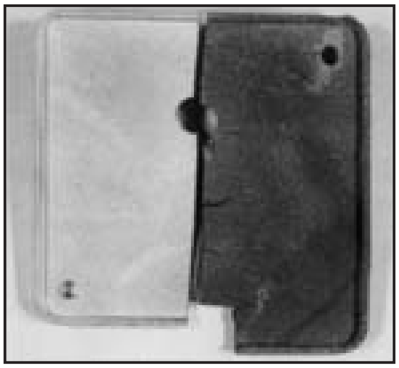
(c) Increase cooling around sprue

* Modifications not usually made by the personnel concerned with operating the diecasting machine and/or not necessary with a die which has previously run successfully.

Chart 1

Visual Defect Identification

For each photograph the name of the defect, its cause, and the point in the manufacturing process at which it occurs is given.

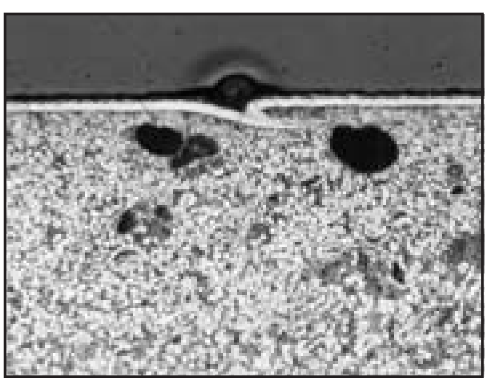


Cominco

1. Intergranular corrosion-contamination- melting

JMB/23

3. Shrinkage porosity - lack of feeding-casting



BNF

4. Gas porosity- air entrapment- casting

JMB/0203/36

5. Hot tearing - composition, hot spots-casting

IZA-6931

6. Cold flow-fill time, die temperature- casting

ZDA

7. Cold flow section with plating-casitng

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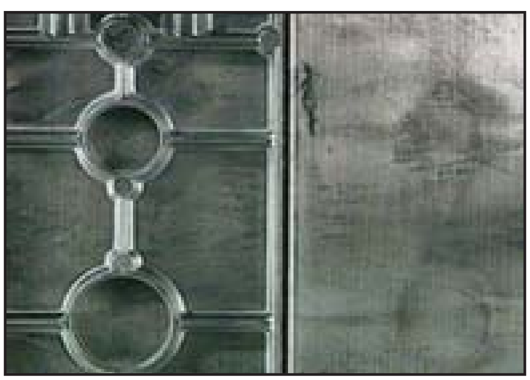
IZA-6937

9. Misrun-fill time, die temperature casting

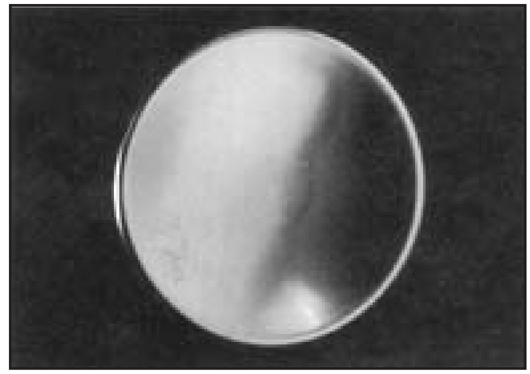
IZA-6940

10. Shot-presolidification-casting



IZA-6943

11. Sink hotspot-casting



ZDA

12. Lake- temperature distribution-casting

IZA-6952

13. Blister-air entrappment - ejection, painting

IZA-6954

14. Drag-die making, soldering-ejection

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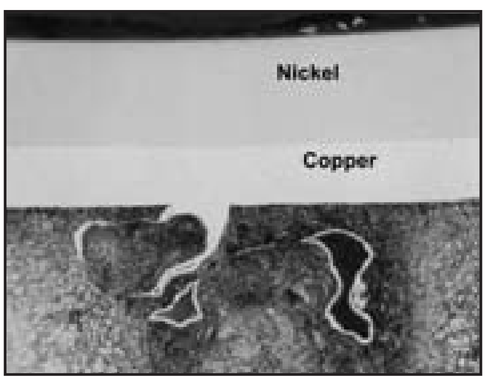
IZA-6952

15. Distortion-die making, temperature-ejection

IZA-6949

16. Flash-pressure-casting

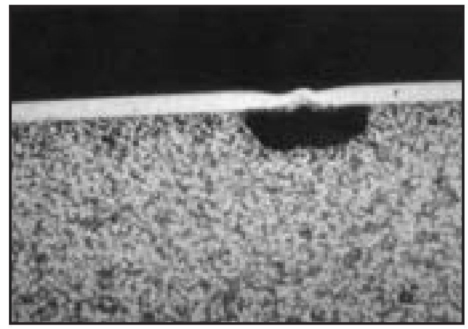


Cominco

17. Gate line porosity-design-trimming

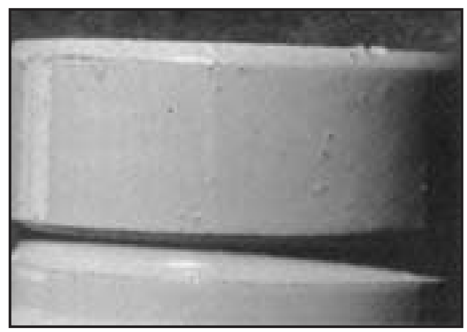
IZA-6034

18. Scaling-cold flow-dressing



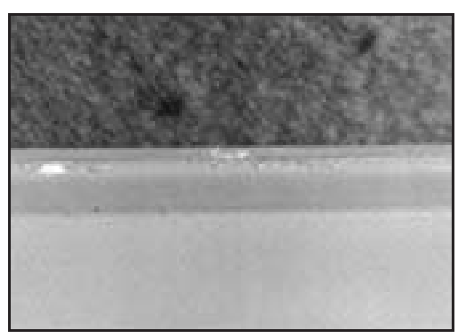
ZDA

19. Corrosion-porosity-plating



ZDA

20. Cissing-cold flow-painting



ZDA

21. Chipping-folding-painting

Chart 2 — Defects Related to Process Operations

Ingot Melting Recycling	Intergranular corrosion Reduction in strength Soldering Hot tearing Fluidity Hard spots
Casting	Misruns Laps Soldering Drag Spatter Porosity Blistering Distortion Sinks Cracks Die wear
Trimming Dressing	Scoring Distortion Break-in Gate porosity Earring Folds Scaling
Assembly Machining	Tool life Fracture
Coating	Distortion Blisters Chips
Handling Storage Packing	Distortion Corrosion Marking

Click Here to Close This Chapter