I Have Defects - Now What?

Morris Murray, Owner
M. Murray & Associates Pty. Ltd.
Victoria, Australia

Lars Feldager Hansen, Associate
M. Murray & Associates Pty. Ltd.
Skive, Denmark

Carl Reinhardt, Associate
M. Murray & Associates Pty. Ltd.-
South Africa

Introduction

Die casting seems to bring out problems on a regular basis. We get a fair share of people ringing up or emailing from around the world with various problems of different complexity. The majority of these are fairly easy and can be solved relatively simply and inexpensively. Some are far more difficult.

We decided to look at problems received in the last few weeks and go over what was successfully actioned to solve these common problems. Due to confidentiality, we cannot show real parts. Therefore, we have come up with a "typical" part with a runner/gating and cooling system that would have most of the common problems.

The part with all the problems

Here is a part that is based on a box and has some interesting features.

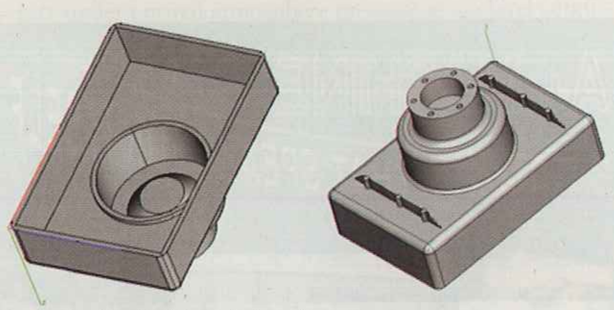

Figure 1 - Typical part being die cast.

The casting is a relatively difficult part, due to the central tube and the thick center. Note that the center has a conical raised up section on the inside. It also has a thick tube at the top, on the outside. This means that the center is fairly thick and will give out a lot of heat during freezing of the casting.

In the following pages, this part will be "put" into a die that is cooled using a system that causes problems in castings that we have seen. The runner will be designed so that the casting will have many of the problems or casting defects.

Cooling System- How not to do it

The cooling here is just around the insert and not where it should be. Why do die casters do this? It is easy to machine in cooling around the outside of the part. This allows the die designer to put in ejector pins and reduces the cost of the tool during production.

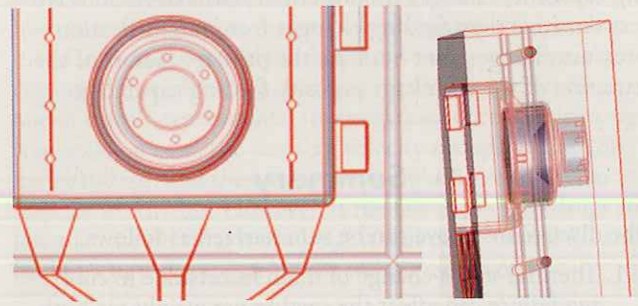

Figure 2 - Die drawings showing typical cooling that many die casters use.

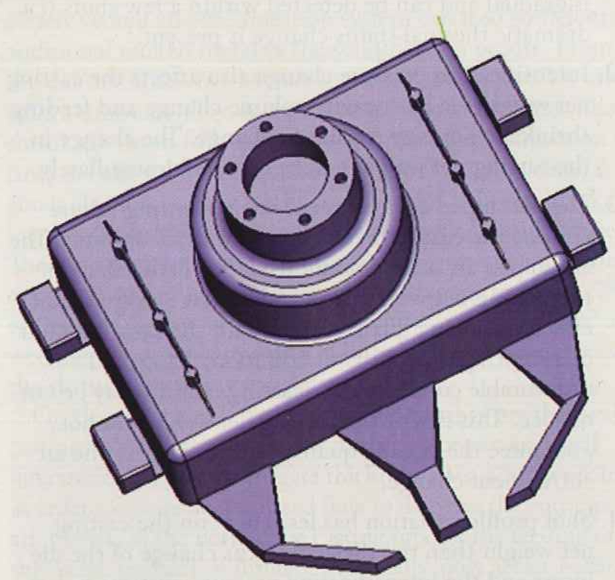

Figure 3- Bad runner design typical of what we see. Too many overflows also.

The runner design shown in Figure 3 is typical of the bad runners we see. It is easy to draw it up, but has big problems. The casting will have many problems and the runner will cause cavitation damage of the die.

We will now review the expected problems of combining these two together.

So What are the Problems?

The runner design, gating and thermals would have these problems.

1. Cavitation damage- The edges of the fan gate would have cavitation damage because the metal is being asked to suddenly change direction where the runner meets the fan gate. This cavitation would show up both in the gate area and into the cavity.
2. Soldering- The center tubular area of the casting is reasonably solid, but there is no cooling near it. The die would get very hot and would be very prone to soldering.
3. Cold Flow- The edges of this part are closest to the cooling and are near the coldest part of the die. Hence, the metal would quickly solidify before the cavity is filled. It would be difficult to make this part without cold flow.
4. Poor Fill- The flow from the gates is not directed to the two sides of the box. Hence, the sides of the box are filled by secondary flow and would have poor fill.
5. Gate and Core Erosion- In order to make this part under these conditions (cold die and secondary flow into some areas) the average die caster would have to increase the plunger speed so as to make the part quicker. This would mean that the metal would not have time to freeze. However, this course of action would erode the gate and the center core.
6. Porosity- The central tube also does not have any direct flow from the gates. Hence, this section of the casting would have a reasonable amount of gas porosity. Due to the lack of cooling, this section would solidify either last or close to it. Hence, it would be expected that it would have shrinkage porosity.
7. Flash- The high plunger speeds would give a high impact at the end of cavity fill. This would result in a very high pressure being applied on the reasonably hot metal. This casting under these poor conditions will probably flash badly.

So, the casting would have a number of difficulties and a number of defects (Figure 4).

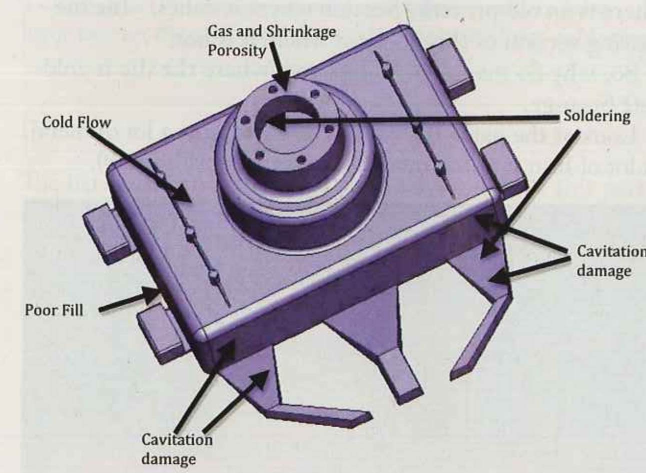

Figure 4 - Casting with runner showing problem areas.

Because of the outside cooling and the poor fill pattern, the average die caster will fill this as fast as possible. This will mean that the gate velocity is too large, the central core is eroded away, the casting flashes, there is soldering of the central cylindrical core and it needs continuous cleaning of the die. The die spray would be critical and the die caster would play with the lube dilution ratio to try and get the part out of the die but this will also cause black marks on the casting. The area around the cylindrical area will also heat check rapidly and bits of die may fall out. The die caster will blame the die steel producer for producing a bad batch of steel. The die caster will probably try to get "super" steel for the core to try and get some life. The trouble is that all of these problems are caused by the die caster/die designer.

- No one is trying to sabotage your plant.
- No one is sneaking into your plant at night.
- There are no gremlins or bad batches of die lube or die steel in this case.
- It is all, totally, caused by YOUR decisions!

Working Through The Problems

Flow Through the Runner

It should be remembered that the metal is usually travelling at 30-100 mph (50-160 kph) in the runner. That is very fast, but not a problem. You can use huge runners if you want to, but these require a lot of cooling in the die, they waste metal, they often add porosity to the metal and they waste energy. So, why not just do things right and use appropriate runners?

So, let's just work through the problem. The metal is travelling fast and does not want to go around corners. It will always take the direction that is as straight as possible unless you force it to change direction. The runner design will simply cause the metal to flow as shown in Figure 5.

As the metal separates from the die in the fan gate, it will cause a vacuum to form and this will introduce vacuum bubbles in the metal. These bubbles flow with the metal and explosively collapse on the die. This causes huge stresses in the die and damage1-2. The gate will then be damaged as well as the core just above the gate (Figure 5).

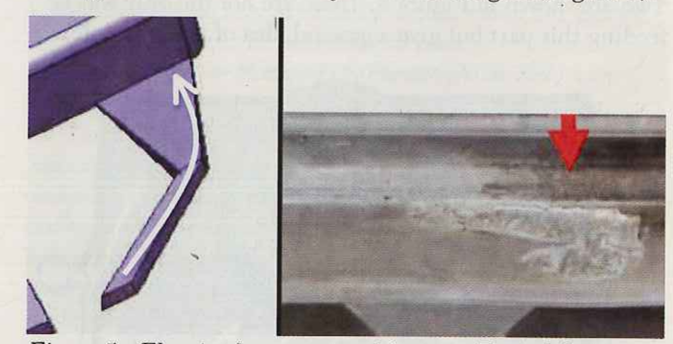

Figure 5 - Flow in the runner and fan gate. Typical die damage from cavitation.

To fix this you would use smooth changes in direction and design the fan gate so that the cross sectional areas decrease along the flow direction. It may mean moving the casting cavity a little further from the shot sleeve or sprue, but the slight extra cost in die steel is worth it.

The radius of the bend should be about 2x the width of the runner in that area. So if you have a 0.6 inch (15mm) wide runner then the bend should have a radius of 1.2 inches (30mm).

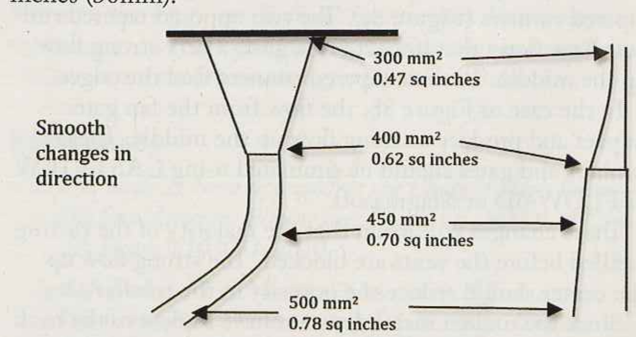

Figure 6 - A better runner with smooth changes in direction and a reduction in area along the flow direction.

Flow in the Cavity

The flow from the gates results in the metal flowing around the central cylindrical area and filling the box section first.

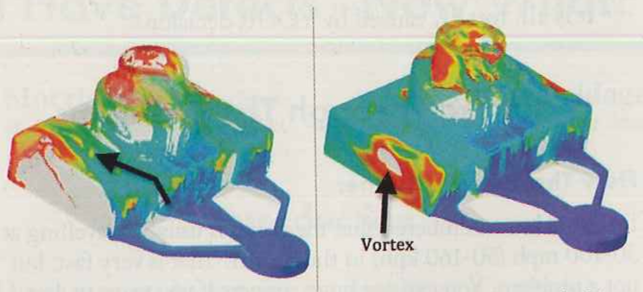

Figure 7 - FLOW-3D simulation of the flow showing (left) main flow past the central tube and (right) a side view showing the "air" left in the casting.

After that, the metal will be forced to flow into the cylinder.

The metal flowing around the side will tend to flow up and over and then cause a vortex in the side (Figure 7). This will result in poor fill of the side. Adding the overflows will not help this flow as the vortex will still form.

The metal is easily deviated around that central tube (Figure 7) and hence has to be forced into the area. Also, once a flow of metal goes around a bend, it tends to be deviated even more. Therefore, it is important to fill the central tube. This can be carried out in a number of ways. Two are shown in Figure 8. These are not the only way of feeding this part but give a general idea of the principle.

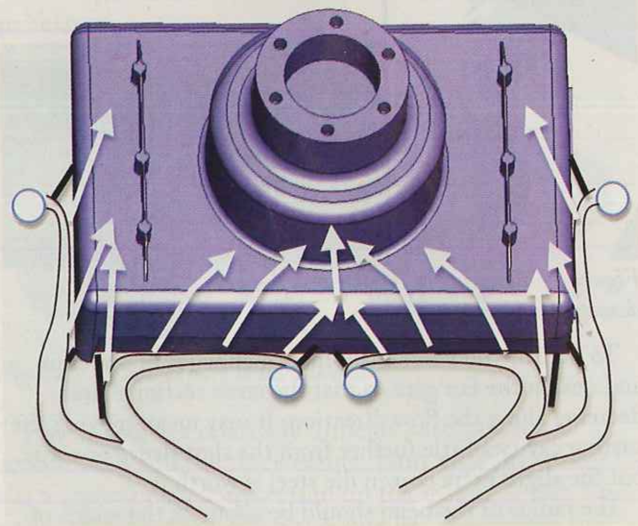

Figure 8a - Twin tapered runners. The flow is out at 45 degrees.

In this case, the flow comes out at 45 degrees from the tapered runners (Figure 8a). The two opposed tapered runners have flows that impact. This gives a very strong flow up the middle. The side tapered runners feed the edges.

In the case of Figure 8b, the flow from the fan gates impact and produce a strong flow up the middle. These runners and gates should be simulated using CASTVIEW or FLOW-3D or Magmasoft.

These changes will mean that the majority of the casting is filled before the vents are blocked. The strong flow up the center should reduce the porosity in the tubular area.

Since the molten metal does not have to flow to the back of the part and then into the central tubular areas, there is no need to have a really fast plunger speed. Reducing this

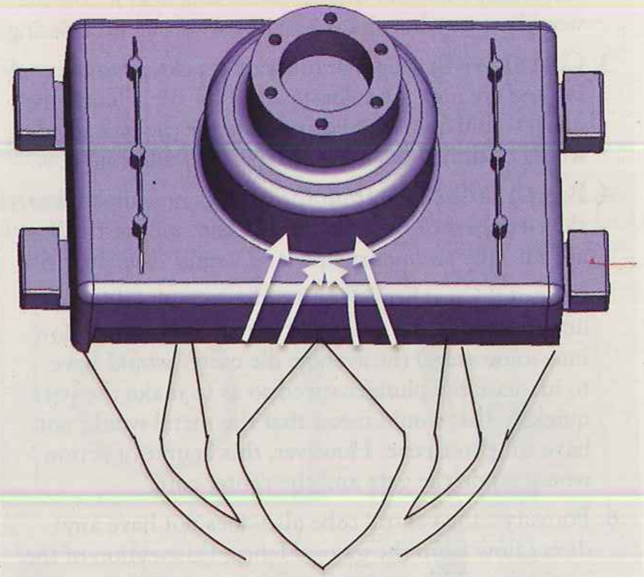

Figure 8b - Another suggestion for a runner using fan gates.

will reduce soldering of the gates and also reduce cold flow. The casting should be easier to make and you won't have to put your shot end in "racing car" mode!

So, now the cavitation is fixed, the flow is fixed, the gas porosity in the central tube is reduced and the machine plunger speed has been slowed down. This slower plunger speed will also, probably, stop the flashing problem. We are starting to get there.

Thermal Problems

There is an old proverb "Scratch where it itches." The die casting version of this is "Cool where it is hot."

So, why do many die casters cool where the die is coldest? Strange.

Look at the part. The central area contains a lot of metal. A lot of heat is going into the central core (Figure 9).

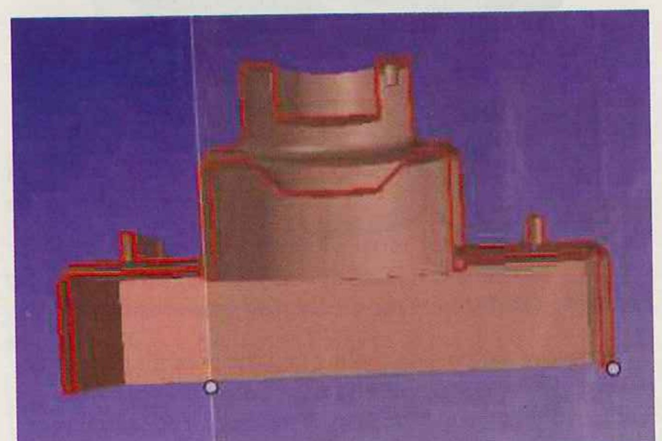

Figure 9 - Section through the part showing metal in center section.

There are two regions that will need cooling. The first is the core at the top of the part. The second is the main core in the moving die. The amount of cooling can be calculated using the MMAA Calculator or the NADCA calculator. However, a rough guide is to have a fountain or bubbler (depending on what you call them) in the top and either a ring cooling or a series of bubbler/fountains. A start is shown in Figure 10. This will at least cool the hottest parts of the die.

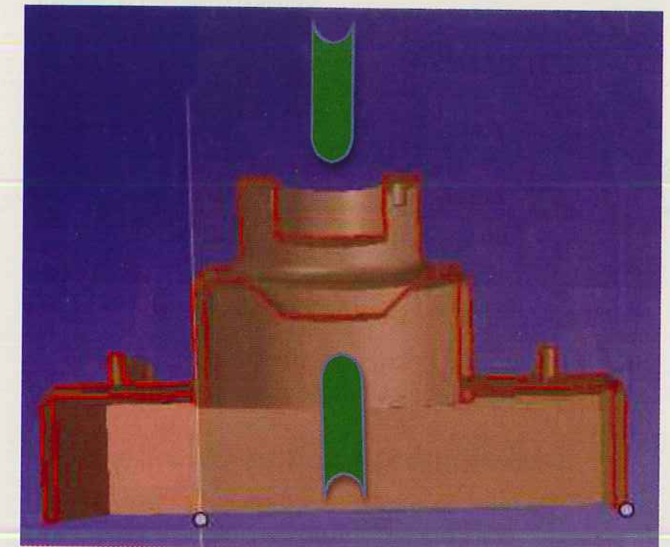

Figure 10 - Possible method of cooling in the die.

Because the die is now cooled via internal cooling, the die spray can be dropped back a lot. This will reduce the cycle time of the process and hence you will produce more parts per hour. The second benefit is that the cores are now not being overheated by the metal and then overcooled by the die spray. The six small cores will still need to be cooled by die spray, but they are small and will rapidly cool using the die spray. This reduction in die spray usually results in a very definite improvement in die life. So, instead of buying a super steel, you can rely on the more traditional steels and still get a good die life.

The soldering will be reduced. Soldering needs heat and a clean die. Removing the heat and placing a thin lube layer on the die will therefore inhibit most of the soldering.

Conclusion

The list of defects at the start of this article made this part a "difficult" part to make. Yet it is the decisions made that meant it was "difficult."

It was shown that the defects could be stopped by some simple solutions.

1. Cavitation Damage- FIXED- The runner was made smooth with good radii. The cross sectional area of the runner decreased along the flow length.
2. Soldering- FIXED- The central core soldering was fixed by cooling it. The gate soldering was fixed by decreasing the plunger velocity. High plunger speeds were not needed as the metal flowed through the die progressively.
3. Cold Flow- FIXED- The side walls were given a better flow by either adding a side tapered runner or by directing metal into the area.
4. Poor Fill- FIXED- The poor fill was caused by poor metal flow. The metal had to flow to the back of the cavity and then flow back into the cavity to fill the central area.
5. Gate and Core Erosion- FIXED- Erosion is reduced by redirecting flow and by reducing speed. The increased gate length means that less metal is flowing past any particular section of die. The controlled flow pattern also means that the plunger speed can be reduced.
6. Porosity- FIXED- The better flow into the central tube would reduce gas porosity. The cooling in the two cores in the center will reduce shrinkage porosity.
7. Flashing- FIXED- The flashing is aggravated by the high plunger speed. Controlling the flow means a lower plunger speed can be achieved, and hence the flashing is reduced.

We solve problems every day for the die casters. We assist the industry in hundreds of problems every year. The proof is in the practical, real results achieved.

Your defect problems can usually be solved relatively easily.

About the Authors

M.T. Murray — Dr. M.T. Murray, founder of M. Murray & Associates Pty. Ltd., is a recognized authority in die casting with more than 30 years of experience in the field. As a senior principal research scientist at CSIRO (Australia), he led their die casting research for a number of years. He has carried out practical research for many OEMs and major manufacturers in such areas as casting design, alloy development, metal and casting quality, molten metal flow systems, thermal analysis and heat control of dies, proving the hydraulic performance of casting machines and optimizing die spray. Murray has authored more than 130 technical papers and has 25 patents. He has also presented a number of training courses on a variety of topics to both national and international companies. He has authored 11 training manuals that cover most topics of die casting. Murray has been the editor of the Australian Die Casting Association's magazine for more than 20 years.

Lars Feldergar — Hansen L.F. Hansen (M.Sc.Tech) is an associate of M. Murray and Associates Pty. Ltd. and trades as 4C-Technologies in Denmark, Europe. He has more than 20 years experience in the die casting field with specialty in computer analysis of heat and metal flow. Hansen worked three years as a die casting project manager at the Technical University of Denmark before he continued as a R&D manager in a large European die caster where he worked for several years. He continued as a die casting expert at Ford Motor Company (Volvo Cars) in Gothenburg, Sweden, with focus on introducing light weight magnesium components in cars before he founded his own advising company 6 years ago. Hansen has done several hundreds runner and thermal designs that all have been proven, as well as on-site optimizations of running productions throughout the world.

Carl Reinhardt — Carl Reinhardt (M.Sc, B. Sc) has been in the foundry industry for over 10 years. His research for his MSc was in semi-solid aluminum production. Reinhardt started out running his own foundry but was then employed as Foundry Manager in a high pressure die casting plant. Reinhardt has been a consultant for 3 years and has recently developed a low cost/ "high" capability process monitoring system for die casting machines. He has a wide experience in die design and training for brass, aluminum and zinc, and has carried out benchmarking for the local industry.

References

1. *J. V. Skoff "A New Approach to the Cause of High Pressure Die Steel Erosion, Pitting and Breakout", NADCA Expo '10, Paper T10-051, 2010.*
2. *A. J. Davis, M.T. Murray, "Cavitation Effects and Die Erosion in the Diecasting of Zinc Alloys", Trans. 11th International Congress, SDCE, Cleveland, Paper G-T81-123., 1981*