ANALYZE OF THE POSSIBLE CAUSES OF POROSITY TYPE DEFFECTS IN ALUMINIUM HIGH PRESSURE DIECAST PARTS

Ferencz Peti[1], Lucian Grama[2]
[1]SC CIE Matricon SA Târgu Mureş, Romania
[2]"Petru Maior"University of Târgu Mureş, Romania
pferencz@ciematricon.ro, lgrama@upm.ro

ABSTRACT

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity. The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mold during the process. Most die castings are made from non-ferrous metals, specifically zinc, copper, aluminium, magnesium. Depending on the type of metal being cast, a hot- or cold-chamber machine is used.

Die castings are characterized by a very good surface finish (by casting standards) and dimensional consistency.

The most common deffect that appear in castings is the porosity type of deffect, which can be gas porosity, shrinkage porosity or leaker.

Keywords: High pressure diecasting, aluminium, porosity, mold, casting deffects

1. Introduction

This paper presents the porosity type of deffects in the high pressure diecast parts and the main causes that have influence on the porosity type of deffects. Also this paper presents the most common control methods for the detection of the porosity type of deffects and the way to prevent and to reduce the porosity since the product / process development phase. In the paper are presented the standards in terms of porosity of the most important car's and components manufacturers.

2. Porosity type of deffects

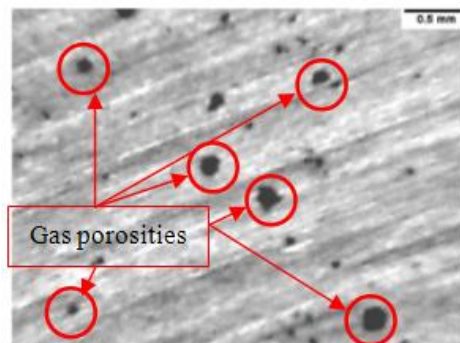Porosity type of deffects reduces the quality of the casting usually it's tightness and strenght.

Fig. 1. Air Porosity in the section of an aluminium diecast part

The most common porosity type of deffects that appear in aluminium castings processed with high pressure diecasting technology are gas porosity, shrinkage porosity and leaker.

Gas porosity can be described as trapped air in the casting which can come from several sources. It can be caused by poor shot end control, poor venting and overflow function or bad gating and runner design.

In the figure 1 is presented the polished section of a diecast part with gas porosity.

It can be observed the specific shape mostly regular – globular and the opaque shade of the gas porosities.

The shrinkage porosities can be described as internal cracks in the casting which can come from several sources, mainly due to thick walls of the casting. This defect is caused by metal reducing its volume during solidification and an inability to feed shrinkage with more metal before solidification. Hot spots can also cause shrinkage porosity to be concentrated in a specific zone.

In the figure 2 is presented the polished section of a diecast part with shrinkage porosity.

It can be observed the specific shape mostly iregular – longitudinal and the bright shade of the shrinkage porosities.

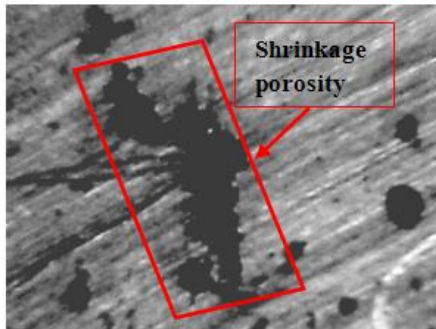In the figure 3 are analyzed the dimensions of the shrinkage porosities with the microscope.

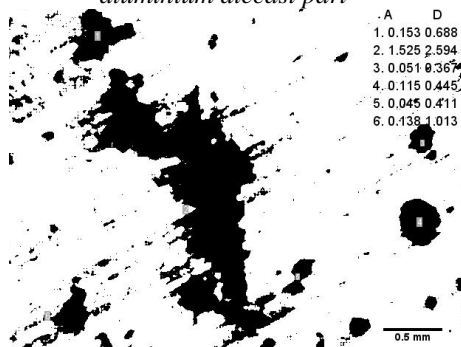*Fig. 2. Shrinkage porosity in the section of an aluminium diecast part*


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          A     D
1. 0.153 0.688
2. 1.525 2.594
3. 0.051 0.367
4. 0.115 0.445
5. 0.045 0.411
6. 0.138 1.013
                  0.5 mm
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Fig. 3. Analize of the dimensions of shrinkage porosities with microscope

Leaker. Causes of leaks in casting where pressure tightness is required can be oxide folds and/or inclusion and/or porosity in conjunction with a surface defect which completes the part for a leak. A close analysis of the leaking area may reveal which of the many causes is causing the leak.

In the figure 4 is shown the section of an aluminium diecast part with leaker.

Fig. 4. Leaker in the section of an aluminium diecast part

3. Main causes for porosity type of deffects in high pressure diecast aluminium parts

Porosity type of deffect can be caused by several factors and process parameters.

The main causes for <u>gas porosities</u> can be grouped in more chategories and are the following:
- Shot end parameters: <u>First stage velocity too low; First stage velocity too high; Change over point too early;</u> Change over point too late; Second stage velocity too low; Intensification too late; Intensification too low;
- Metal volume: Wrong shot weight setting on ladle; Blocked pour hole; Blocked launder on dose furnace; Tube constricted on dose furnace
- Clamping & Ejection: Irregular operating cycle
- Die surface: Not enough plunger lube/sticking plunger; Die is too cold; Too much die spray;
- Vacuum & Venting: Leaking vacuum; Vacuum on too soon/late; Ineffective venting and/or overflows
- Die construction: Poor gating and runner design; Difficult casting geometry
- Metal: Metal is too hot/cold;

The main causes for <u>shrinkage porosities</u> are the following:
- Shot end parameters: <u>Metal pressure too low;</u> Wrong deceleration setting; <u>Second stage velocity too low;</u> Second stage velocity too high; Intensification too late; Intensification too low;
- Metal volume: Wrong shot weight setting on ladle; Blocked pour hole; Blocked launder on dose furnace; Tube constricted on dose furnace
- Clamping & Ejection: Irregular operating cycle
- Die surface: Not enough plunger lube/sticking plunger; <u>Die is too hot; Not enough die spray;</u>
- Die construction: Poor gating and runner design; <u>Poor thermal control/ hot & cold spots;</u> Difficult casting geometry
- Metal: Metal is too hot/cold; Metal is contaminated and/or dirty; Metal is out of specification; Dross in holding furnace

The main causes for <u>leaker</u> are the following:
- Shot end parameters: Metal pressure too low; First stage velocity too low; First stage velocity too high; <u>Change over point too early; Change over point too late;</u> Wrong deceleration setting; <u>Second stage velocity too low;</u> Intensification too late; Intensification too low;
- Die surface: Water in cavity/leaking water channel; Leaking oil heating/ cooling unit; Too much plunger lube; Not enough plunger lube/sticking plunger; <u>Die is too cold; Die is too hot; Too much die spray;</u>
- Vacuum & Venting: Leaking vacuum; Vacuum on too soon/late; Ineffective venting and/or overflows
- Die construction: Poor die/ shot sleeve surface finish; Poor gating and runner design; Poor thermal control/ hot & cold spots; Difficult casting geometry
- Metal: Metal is too hot/cold; Metal is contaminated and/or dirty; Metal is out of specification; Dross in holding furnace

4. Porosity control methods

The most known methods for the control of the porosity are with X-Ray; by cutting the parts and polishing the section of the part and for analyse using a microscope; by Computerized Tomography.

The most common methods are the first two. This methods are used by all the producers of high pressure diecast parts.

As state of the art the computerized tomografy for the analysis of the porous deffects in castings is used by companies as VW group. With this method the volume and localization of the porosities can be precisiely determinated and built in numerical 3D models. One case study is presented in the figure 5 for an oilpump cover.
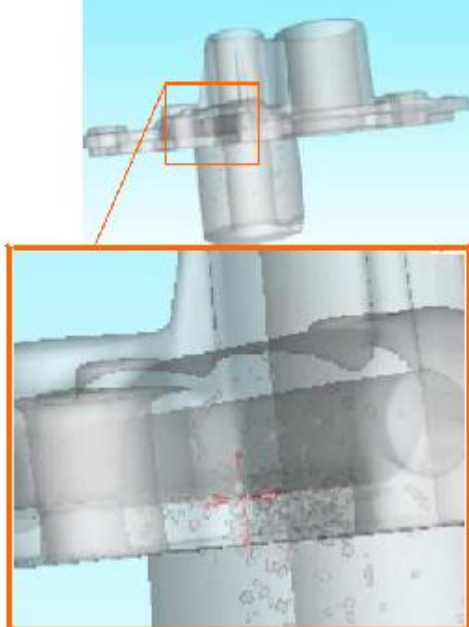

Fig. 5. Reconstruction of the numerical 3D model of an Oil Pump component with Computerized Tomography

5. Standards and specifications for porosity type of deffects in automotive industry

There is a big variety of standards and specifications in the industry related the porosity and porosity type of deffects. For example in the automotive industry we can refere to the following standards and specifications: ASTM E505 the american Standard Reference Radiographs for Inspection of Aluminium and Magnesium Die Casting; VDG Specification P 201- the German Standard for Volume Deficits of Non-Ferrous Metal Castings.

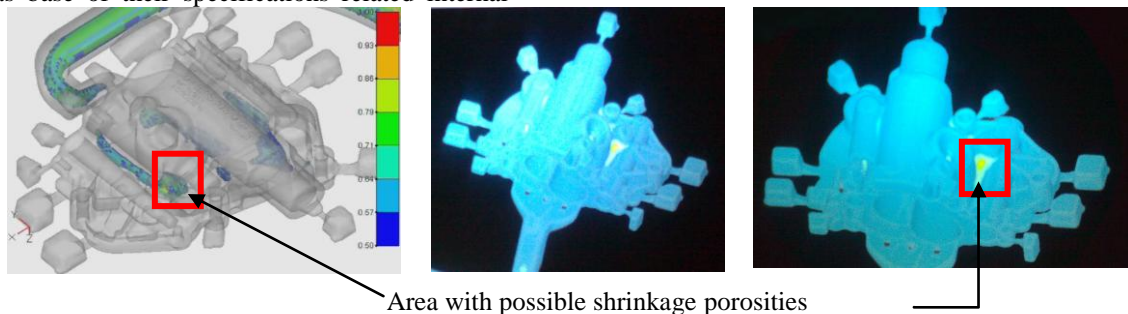Most of the car components manufacturers have as base of their specifications related internal health of material in the diecast parts these two standards. Companies as Ford, Renault group, TRW, JTEKT use the ASTM E505 for the definition of porosity type of deffect.

Volkswagen Group for porosity specification use the VDG Specification P 201.

6. Simulation with FEA of Flow and solidification

The purpose of the flow simulation is to develop and improve the shape of the part and also of the runner in order to have an optimum filling of the cavities and to identify the last filled areas where the overflows have to be placed in order to assure good wenting of the cavities and minimize gas porosity defects.

For the flow simulation can be used softwares as Flow3D.

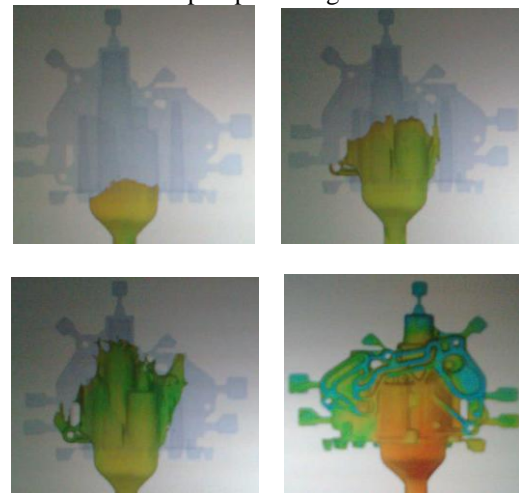In the figure 6 is presented the flow simulation in the case of an oilpump housing.

Fig. 6. Analyze of the cavities filling with Flow3D software

With the same software is performed the solidification simulation which has the role to identify the areas where the part presents areas with liquid fractions after the optimum solidification time which can cause shrinkage porosities.

Area with possible shrinkage porosities

Fig. 7. Solidification simulation with Flow3D software

The shrinkage porosity appears in areas where is concentrated big mass of aluminium, where the thickness of the walls is to high. In the figure 7 is presented the solidification simulation in the case of an oilpump housing.

7. Mathematical equations of metal flow

Simulation softwares for filling and solidification have at there base complex mathematical ecuations. The filling of the molds cavity is done with molten aluminium.

The liquid aluminium respects the equation of the Fluids flow. In the figure 8 is presented the equation of the fluids flow.

$U = (u, v, w)$ - speed of fluid;

P - pressure;

G- gravitational acceleration;

t - viscosity tensor of effort;

K U- braking coefficient

RSOR U/r- acceleration cauzed by the injected mass of aluminium at zero speed

F- other forces.

$$\frac{\partial u}{\partial t} + \left\{ u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} \right\} = -\frac{1}{\rho}\frac{\partial P}{\partial x} + G_x - \frac{1}{\rho}\Delta\tau_x - Ku - \frac{RSOR}{\rho}u - F_x$$

$$\frac{\partial v}{\partial t} + \left\{ u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} \right\} = -\frac{1}{\rho}\frac{\partial P}{\partial y} + G_y - \frac{1}{\rho}\Delta\tau_y - Kv - \frac{RSOR}{\rho}v - F_y$$

$$\frac{\partial w}{\partial t} + \left\{ u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} \right\} = -\frac{1}{\rho}\frac{\partial P}{\partial z} + G_z - \frac{1}{\rho}\Delta\tau_z - Kw - \frac{RSOR}{\rho}w - F_z$$

Fig.8. Fluids flow equation

8.How to reduce porosity type of deffects?

The simpliest way is to do a good process definition and setup since the beginning and to keep it under control by assuring the stability of the process. The stability of the process can be assured by monitorizing and keeping under control the process parameters. The monitorizing can be done automatically by the diecasting cell or with frequencial controls defined in process failure mode analysis and in control plans.

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