COLD FLOW

Description:

This defect is characterized by irregularities in the casting surface as wrinkles or laps. Most commonly it is caused when a filling flow under relative low temperatures and velocities meets another. The defect can be much worst when there is air entrapped at the moment that the two flows come together. This defect can happen also at the end of the filling flow (Fig. 1a & 1b), in this case it is also called misrun.[1,2] Other variants of this defect receive different names as cold laps, cold fill, cold joints, joints and can slightly change in the appearance, but the root cause is usually similar.

Fig. 1a: Cold flow in the casting[(3)]

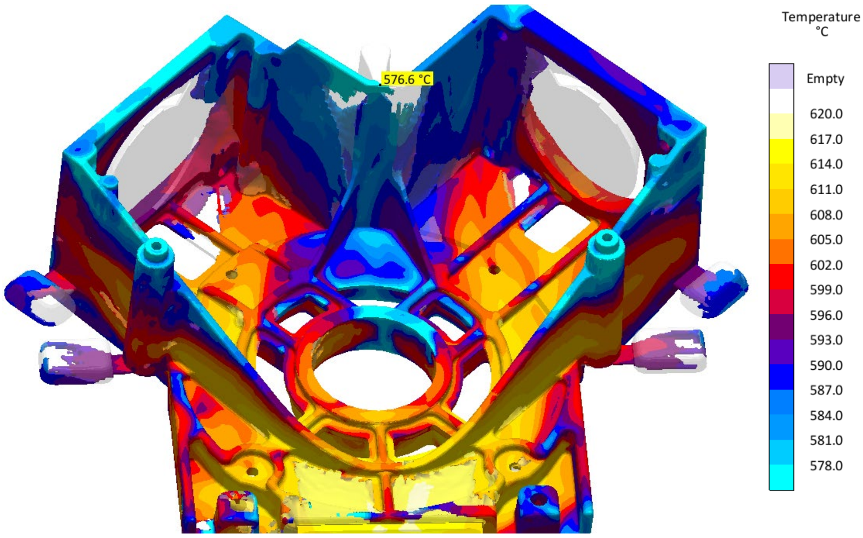


Fig. 1b: Filling temperature profile, showing melt flow temperatures below the liquidus temperature at the end of the filling[3]

Simulation Interpretation:

A detailed analysis of the cavity filling temperature and velocity behavior allows to visualize filling pattern. Filling temperature criteria (in general criteria) shows the temperature when the filling reaches a certain surface. Critical temperatures are below the liquidus temperature of the alloy, where viscosity increases because of higher fraction solid in the melt flow. Low velocities and high air pressures at the flow fronts or at the end of the filling, can show similar defect characteristics even with relative high temperatures.

Possible Root Causes:

- Low temperatures of melt or mold surface
- Shot curve with relative slow velocities of the 1st phase and/or 2nd phase
- Switch over point inside the cavity – pre filling
- Lack of opportunities to clean/wash the area
- Position of the gates that leads to an uneven flow
- Air entrapped at the flow front

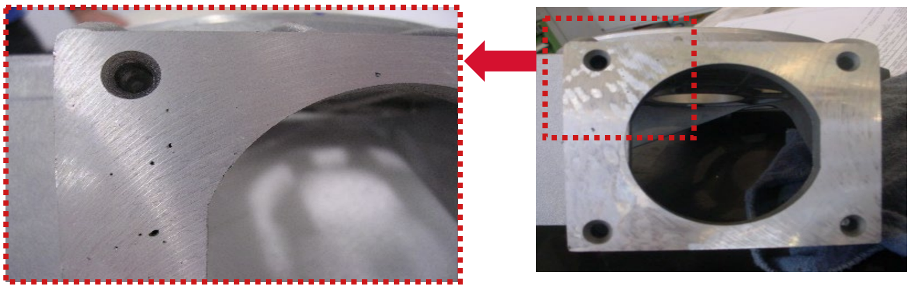


Fig. 2a: Air porosity in the machined surface[3] (Left: zoomin view)

AIR POROSITY

Description:

Air porosity is a gas related defect and it forms as a consequence of air entrapment in the liquid metal. Air porosity looks like a series of rounded and flattened shape bubbles, where the inner surface looks relative smooth with an oxide layer. Usually air porosity appears dispersed under machining surfaces (Fig. 2a). It is the most frequent gas-related defect in high-pressure die casting. The air bubbles can form during the filling at the shot sleeve, at the runner or inside the die cavity.[2 4]

Commonly air porosity defects can be confused with shrinkage defects and they are usually observed together in X-ray analysis and CT Scan (Fig. 2b). As those defects requires completely opposite actions for correction is recommended a simulation analysis and a clear failure analysis to identify the type of the porosity.

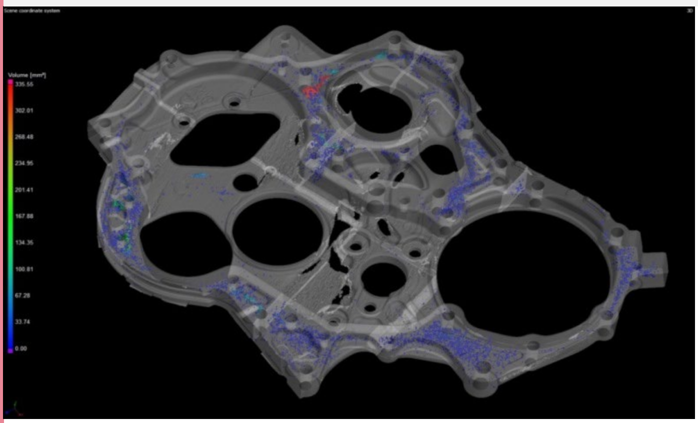


Fig. 2b: CT Scan showing shrinkage & air porosity

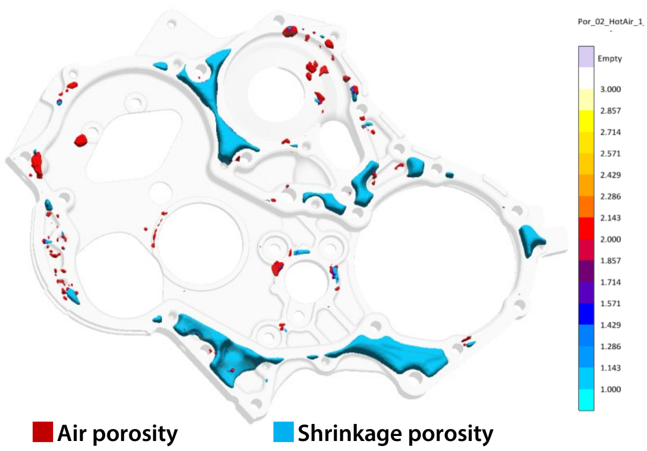


Fig. 2c: Air porosity and shrinkage porosity user result, showing where there is shrinkage and air porosity

Simulation Interpretation:

Results of Air (version 5.5), Intensification Air Entrapment and Air Pressure shows where the air was entrapped and where the final air porosity is placed.

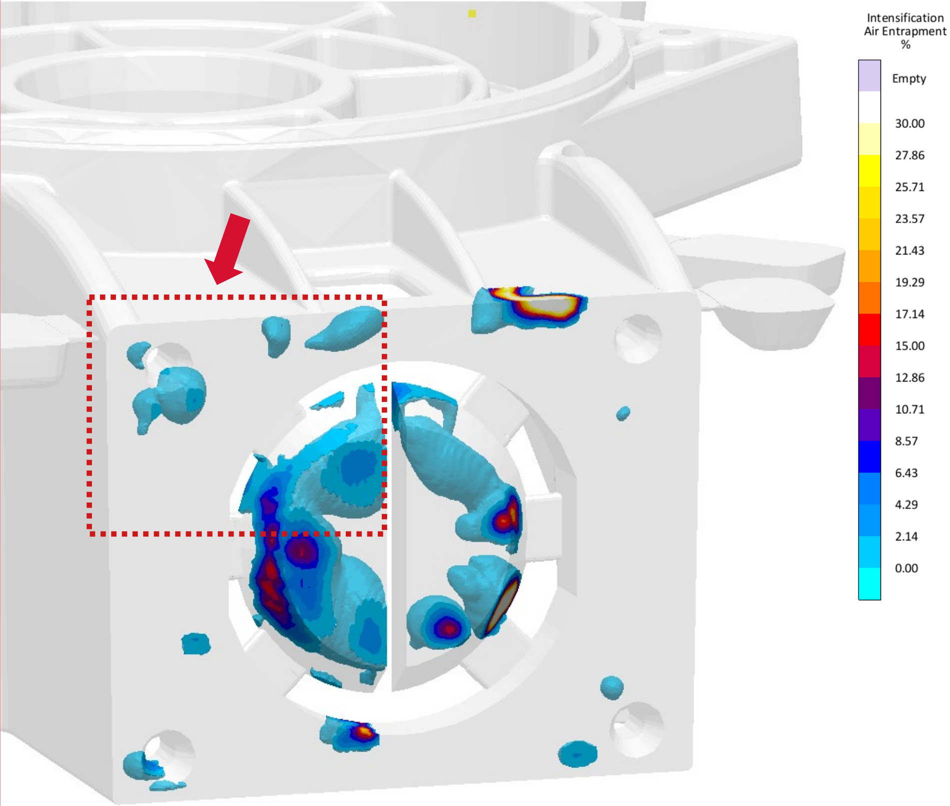


Fig. 2d: Intensification air entrapment shows the final location of the air mixed with the melt[3]

Possible Root Causes:

- Second phase excessive high velocity – air finely distributed in the melt
- Too high or too low velocity of the first phase – air entrapped inside the shot chamber
- Depressurized runner system
- Air entrapped at the end of the flow or at the filling fronts
- Lack of overflows and venting channels
- Improper overflows location
- Small volume of the overflows
- Blocked air vents
- Shot chamber low filling level
- No vacuum or vacuum system not working properly

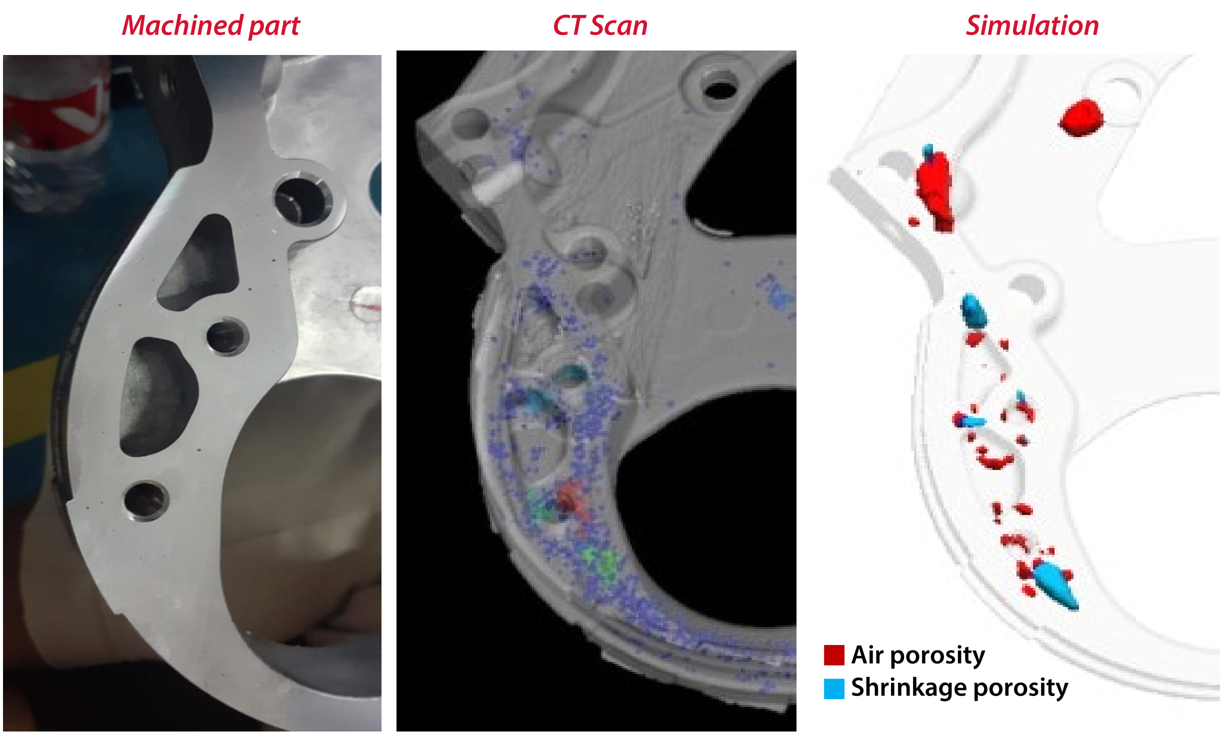


Fig. 2e: Shrinkage & air porosity are shown in above images. From simulation, it is clearly shown that the defect is more related to air porosity.

AIR POROSITY

MOLD EROSION

Description:

Mold erosion is characterized by a bad surface quality of the casting due to die removal material caused by erosive wear (Fig. 3a). Erosion depends on many different factors, but mainly on excessive high velocities at the gates (reference for Aluminum >40 m/s), the inclination angle between the melt flow and die surface (Fig. 3b) and the increase of local temperature of the die.[4]

Another typical erosion effect is cavitation, where gas bubbles trapped in the melt implodes on the die surface, causing pits in the die surface.[2] The phenomena is driven by high velocity in a liquid medium together with a big pressure drop in a very short time.

Fig. 3a: Red arrows indicating erosion areas

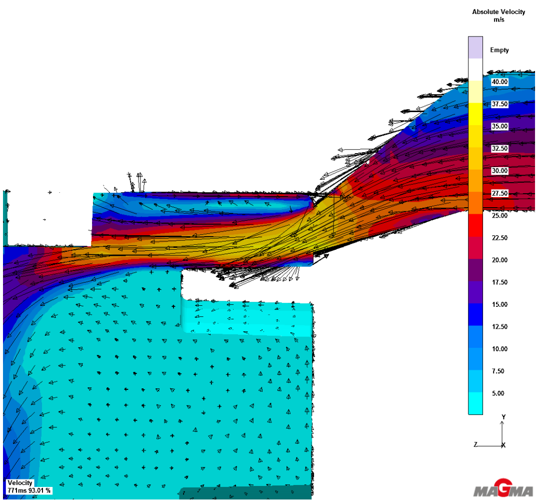


Fig. 3b: Velocities at the gates with vectors activated

Simulation interpretation:

Filling velocity with the aid of vectors shows the velocity and the direction of the flow towards to the die (Fig. 3b). The result of mold erosion shows the areas of the mold that will be affected (Fig. 3d). It's possible to combine results of melt pressure and velocity in order to predict critical regions of cavitation as shown in the user results (Fig. 3e & 3f).

Fig. 3c: Erosions on marine engine gear case

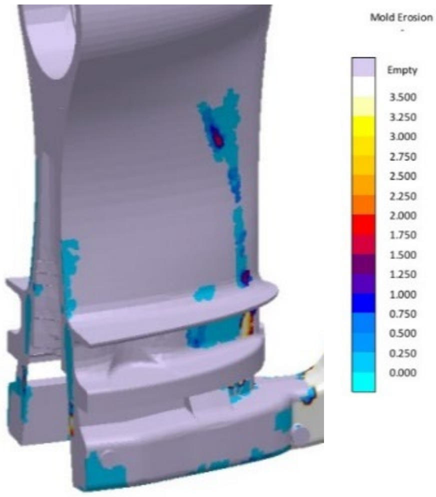


Fig. 3d: Mold erosion results showing critical regions

Possible Root Causes:

- High speeds in the gating area throughout the filling time
- Angle of flow impact in the die
- High local temperature in the point of impingement
- Cavitation

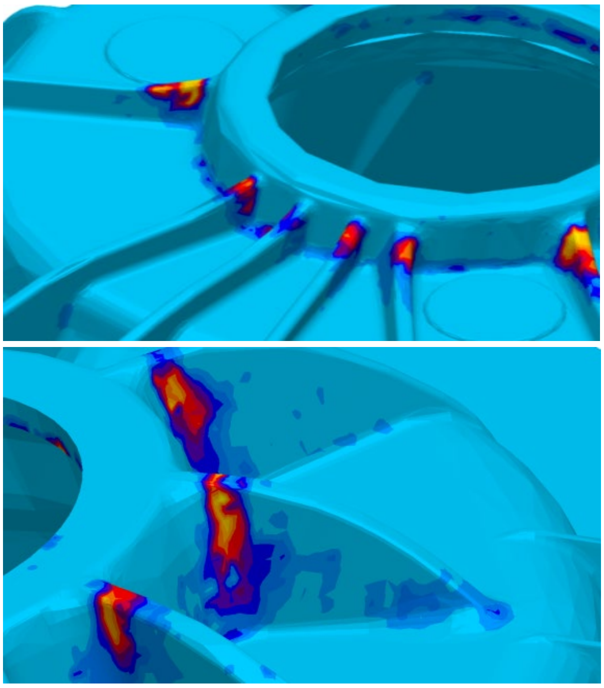


Fig 3e: (Top & bottom left) Excess of material due to cavitation in the mold on castings;

Fig. 3f: (Top & bottom right) Cavitation prediction in user results.

MOLD EROSION

SHRINKAGE POROSITY

Description:

Shrinkage porosities are discontinuities with irregular shape and rough surface with dendritic aspect (Fig. 4a & 4b). These porosities are the result of volume contraction during solidification and occur when liquid metal is no longer available to feed the volumetric contraction of the solidifying metal.[1,2]

- Macroshrinkage porosity is relatively large, located inside the isolated hottest points of the casting. It is usually observed by naked eyes (Fig. 4e)
- Microshrinkage or interndendritic porosities forms in regions of small temperature gradient, when liquid metal cannot adequately feed the interdendritic regions, resulting in microscopic interconnected discontinuities. In many cases interdendritic porosities are the reason for leakage in castings (Fig. 4c). Macroshrinkage vs microshrinkage depends on solidification conditions and alloy solidification range[2,4]

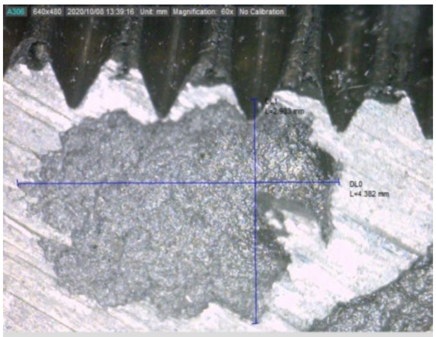


Fig. 4a: Zoom in view of the porosities from Fig. 4e (60X magnification)

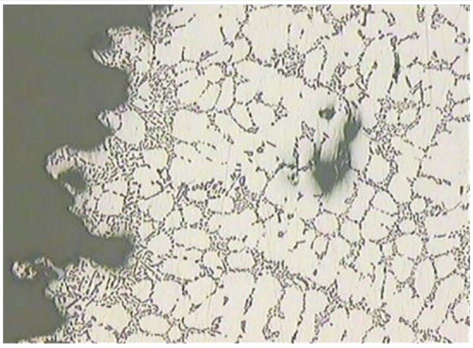


Fig. 4b: Macro-shrinkage is characterized by rough and spongy surfaces due to the interrupted growth of emerging dendrites[1]

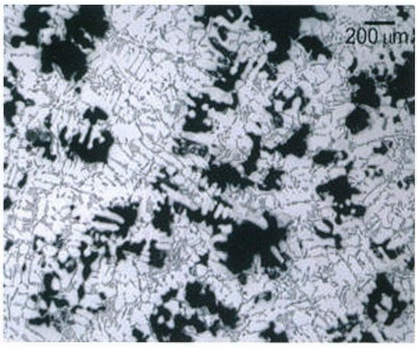


Fig. 4c: Micrograph of a region with interdendritic interconnected porosity[1]

Fig. 4d: Oil pan showing the cut where shrinkage porosity was detected

Fig. 4e: Cross section view of A-A. Image showing the shrinkage porosity in the machining area.

SHRINKAGE POROSITY

Simulation interpretation:

Fraction Liquid and Temperature results show the solidification path and when the hot spot is isolated (Fig. 4f). FStime shows the time that feeding is not possible anymore. Hot spots (Fig. 4g) and Porosity (Fig. 4h) shows the location, volume and intensity of the shrinkage porosity respectively.

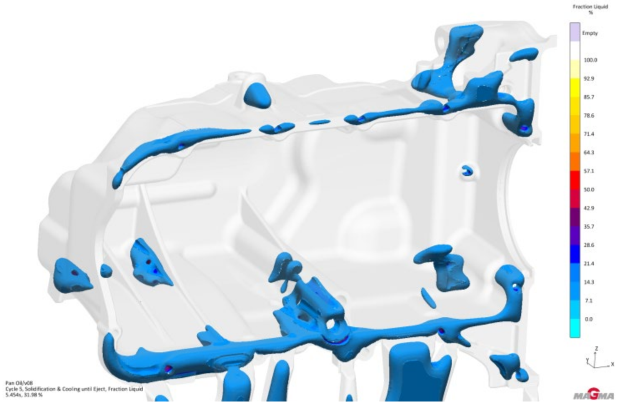


Fig. 4f: Fraction liquid, showing 68% of total solidification. Through this result is possible to identify the feeding paths

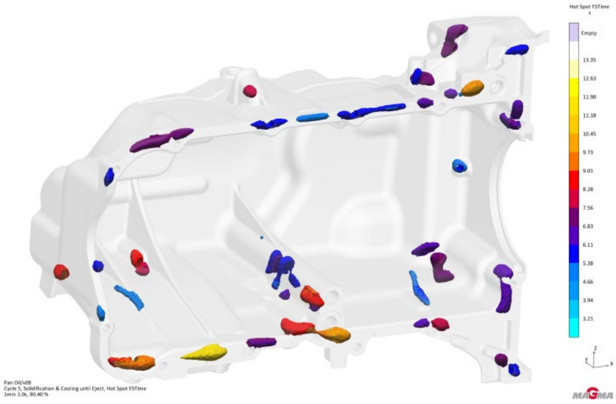


Fig. 4g: Hotspots showing the location of isolated areas

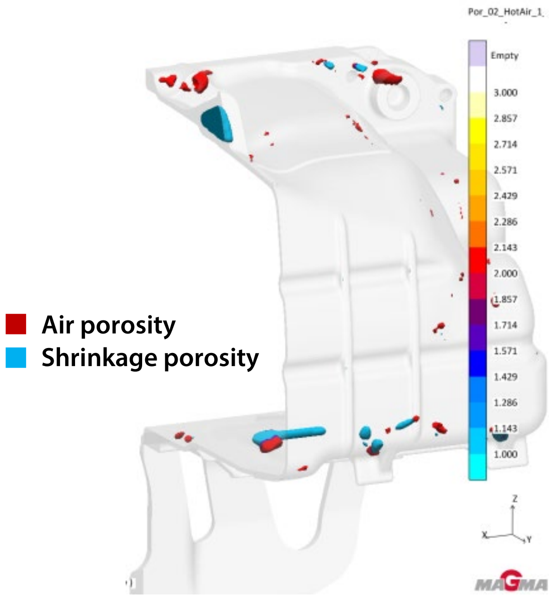


Fig. 4h: Shrinkage and air porosity result identifying that the porosity in the critical region is shrinkage porosity

Possible Root Causes:

- Hot isolated areas in the geometry – hot spots
- Lack of feeding – early gate solidification
- No feeding paths in the component
- Low intensification pressure (3rd phase).
- High temperature of the mold – poor or no cooling at the hotspots.
- Excessive high pouring temperature
- Small thickness of the biscuit
- Poor temperature control / spraying of the mold

SOLDERING

Description:

Soldering is a metal/die interaction defect. It is defined when the cast material combines with the steel, and forms an intermetallic phase that becomes part of the die steel surface. The Aluminum adheres onto this intermetallic phase (Fig. 5a). This effect is accelerated when the die steel is at higher temperatures. Soldered die regions correspond to surface defects on the casting due to build-up on die surface.[1,2,4]

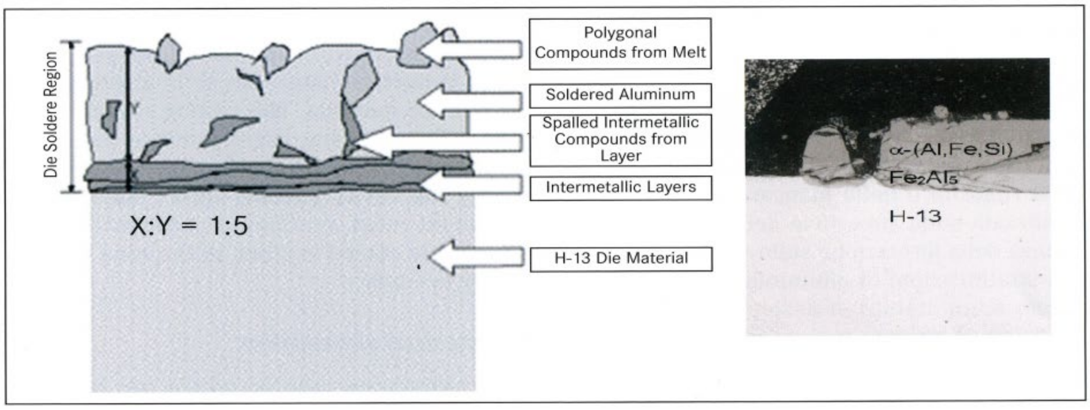


Fig. 5a: Schematics of soldering phenomenon [1]

Fig. 5b: (Left) Soldering effect on the die; (Right) Die damage after soldering [1,3]

Possible Root Causes:

- Cavity design - Presence of deep undercuts and long thin pins
- Small draft angles
- Poor mould surface polishing
- Fail in lubricant application
- Low iron content in the alloy (> 0.7%)[2]
- High velocities - The natural iron oxide coating, an important barrier can be removed by high velocity metal flow[2]
- Locally high temperature of the die – no or inproper position of local cooling channels

SOLDERING

Simulation interpretation:

Soldering criteria shows the regions of the mold with solder tendency (Fig. 5d & 5e). The temperature profile of the mold during solidification shows the regions with high temperatures and poor local cooling (Fig. 5c).

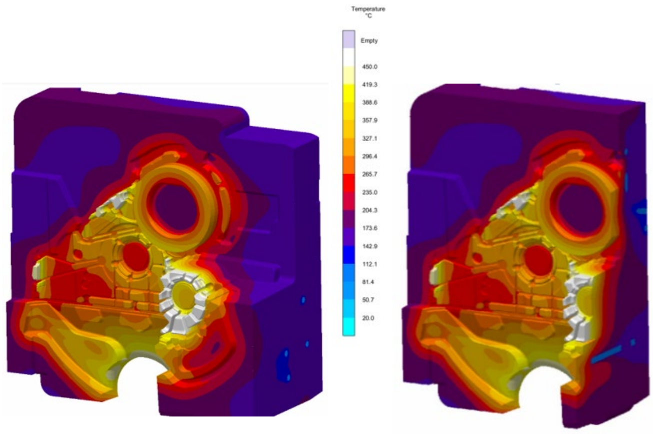


Fig 5c: Mold temperature profile during solidification. It's possible to evaluate high temperature regions and if the cooling channels are in the right position

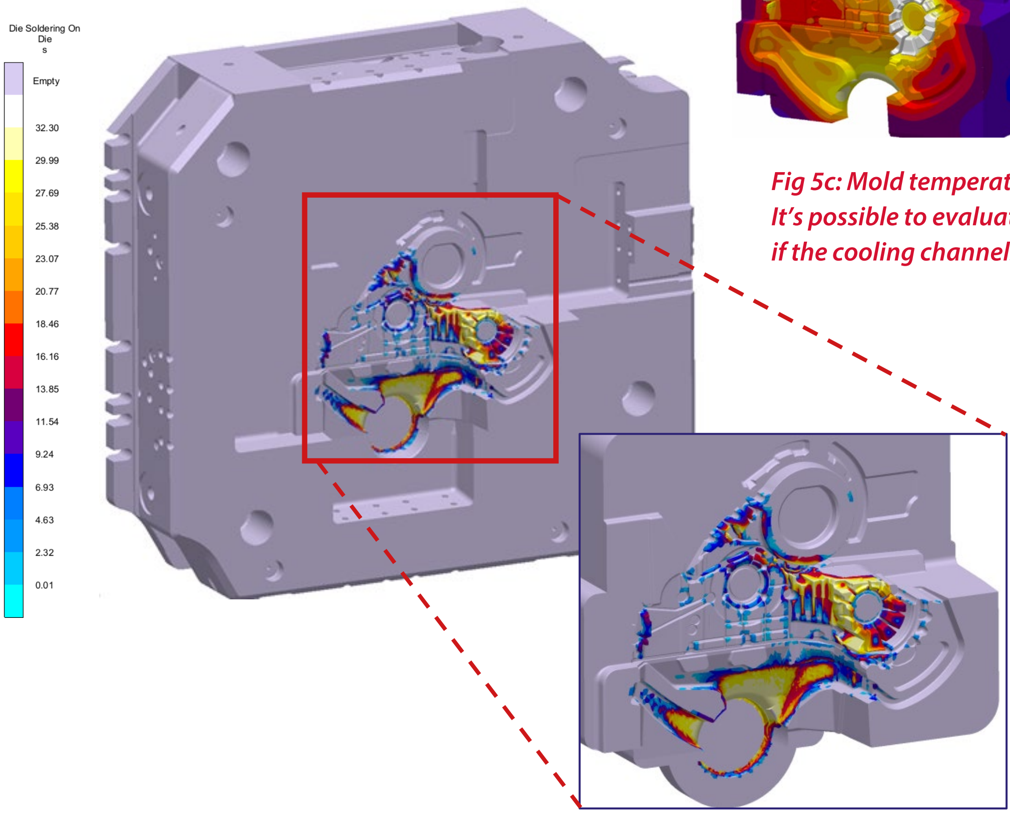
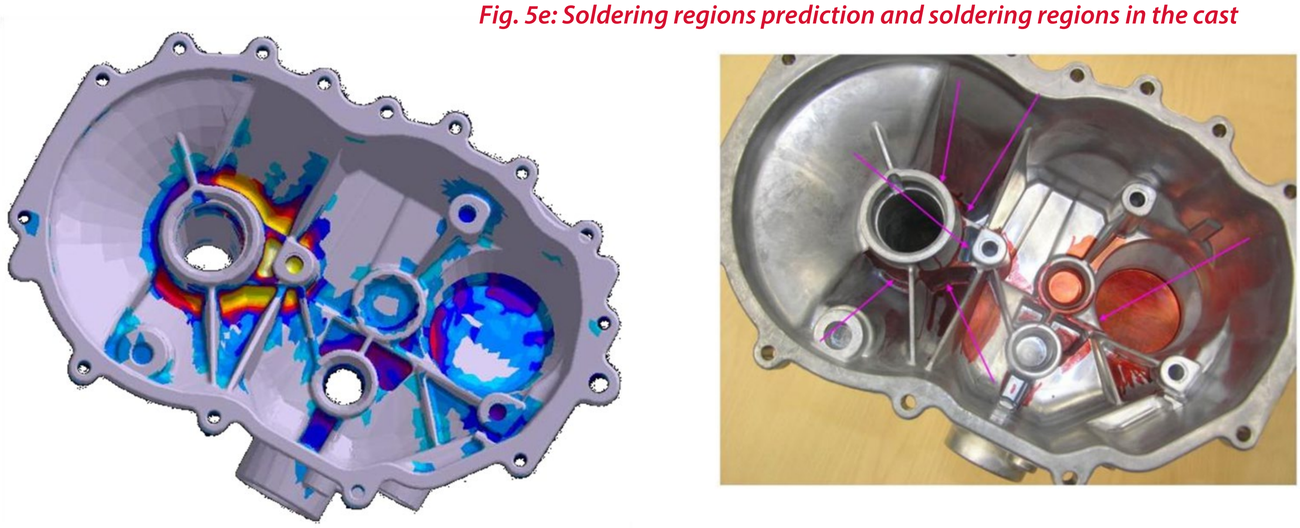


Fig. 5d: Soldering criteria - risk of soldering in yellow regions

Fig. 5e: Soldering regions prediction and soldering regions in the cast



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