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Gas Bubble Tracking During Casting Filling Process

Dr. Xiaojun Yang, Miss. Rajeshwari Sanjay Rawal

Research and Development Department, C3P Engineering Software International, Guangzhou, China

ABSTRACT

During numerical simulation, one of the biggest challenges is to simulate the smallest air bubbles that can be entrained in the metal. In fact, in common fluid-dynamic simulation of casting process filling each time a region of air gets smaller than the element size it disappears, losing all the information about its presence and the possible defects that this implies. If the engineers with enough experience and good background, who can track the regions of air entrapped during the filling process and check manually where they, especially the last ones, close up and disappear. However, this approach is too approximated and does not keep in account the final movement displacement of the bubble.

KEYWORD: *Cast-Designer, CFD, Post Solver*

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I. INTRODUCTION:

Cast-Designer is powerful software, designed specifically for modeling a wide range of casting processes. Cast-Designer consists of thermal solution and a full flow; which is helpful for the die (mold) and the cast alloy. During the simulation, two major factors we must considered: the simulation speed and the accuracy. To find the best compromise between fast and accurate simulations, two gas models have been introduced in Cast-Designer: the air entrainment model and the adiabatic gas model.

The air entrainment model has been developed to simulate the effect of the turbulence in free-surface flows, which may be sufficient to disturb the surface to the point of entraining air into the flow. Due to the microscopic size of the entrained bubbles the air is then diffused into the flow. In order to simulate the bulking of fluid volume and the buoyancy effects which is associated with entrained air and the possible escape of air we use the air entrainment model if it rises to the surface of the metal. During conserving the mass, the air can be compressed and changes its volume.

The adiabatic bubble model, instead, is able to represent bigger bubbles that are closed into the fluid because of the movement of the free surface. A void region or bubble defines as any continuous region of void cells. . Each void region is characterized by uniform pressure, temperature, volume, and inertia; the friction at the interface with fluid can be neglected. These assumptions are generally valid if the gas density is much smaller than the one of the fluid and the gas speed is comparable with that of the fluid, typical of mold filling with liquid metal.

II. METHODOLOGY

The adiabatic bubble model is a powerful model that gives the possibility to track the gas regions during a filling process, influencing the flow dynamic itself and giving the possibility to the user to guess the location of some typical defects connected to the entrapment of bubbles of gas. This kind of defects can be generated by a closed region of air that is core and more compressed during the filling hence can be modeled only with the adiabatic bubble model or a similar approach. . They have a well-defined shape and cannot be modeled with a dispersed quantity in the fluid. Since each bubble can shared the external metal only as a boundary condition, however inside each bubble some specific information (such as pressure and temperature) is stored. The amount of gas itself is also localized: it can be eventually split in more bubbles, but it is generally not diffused into the metal.

For this reason, these defects cannot be simulated using the air entrainment model or the surface defect tracking model of Cast-Designer, because they represent two different kinds of defects. These defects are dispersed into the metal and are entrained from the free surface, where they represent the entrapped gas due to the turbulent free surface, and the oxides and other impurities collected on the free surface.

The adiabatic bubble model has one limitation: in order to work it needs that the bubble is bigger than the element size. When a bubble gets smaller, it collapses losing its information and its effects on the flow. During the last part of the filling, it is required to check whenever a bubble collapses during the simulation; so the way of trying to determine the position of the related defects. Last bubbles generate more defects in the real casting part due to their higher internal pressure. Since this approach does not keep in account the movement of the bubble after it is deleted from the simulation hence not reliable. Moreover, it does not provide any information about the size of the defect itself, because it does not keep in account the evolution of the bubble volume and pressure.

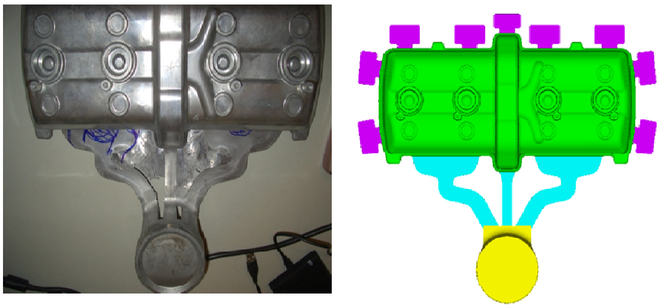

Fig. 1 - Existed gating system with gas porosity defects and surface quality problems, the real casting part and CAE model

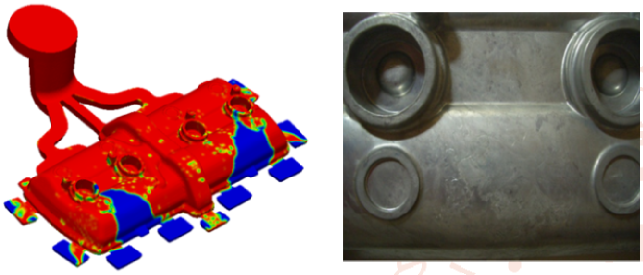

Fig.2 - Cast-Designer CFD simulation shown the gas bubbles and the risk of gas entrapment, also the real casting part shown the surface defects existed on the same region.

To overcome this limit, Cast-Designer develops a new gas solver to track such smaller bubble, called post-solver. In the Cast-Designer post solver, each bubble, and even the smallest one, should be tracked during the filling, varying their size and internal pressure.

More specifically, when a bubble gets smaller than the element size and collapses one or more mass particles are generated through the customization, storing all the information of the disappeared region of gas. At the end of the filling, the intensification pressure com-presses each particle, giving to the user the final position and the exact size of the defect.

III. RESULT and DISCUSSION

To validate the gas tracking method and code, several tests have been done, from the simplest test cases to simulations of real parts, comparing numerical results with experimental analysis.

Fig 1 shows a gear box cover with serious gas porosity and surface defects. Due to the geometry features and the gating system design was not good, the metal flow in the end of the casting part was not balance and gas entrapment has been taken place. The result is the serious surface defects on the casting part. (Fig. 2)

The bubbles distribution near the end of filling also gives clearly information of the surface defects (Fig 3). The bubble gas pressure and maximum pressure of the casting process (Fig. 4) also gave the similar result. So in this case, many criteria could be used to judge the simulation result in this model.

Thanks to the Cast-Designer Post-Solver, each collapsed bubble generates some gas particles that are moved and compressed until the end of the filling. Looking at the result at the end of the simulation, it can be noticed that the highest concentration of gas particles is in the same region where the defects were observed in the real part.

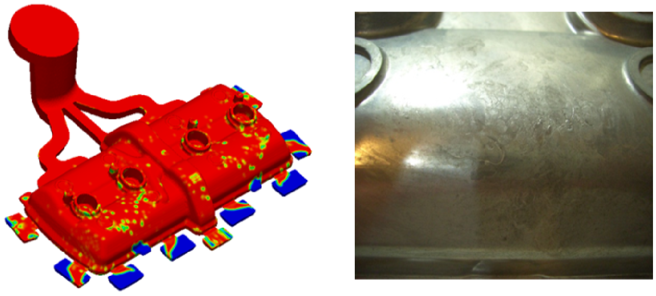

Fig. 3 - Final bubbles in the simulation and the surface defects on the real casting part

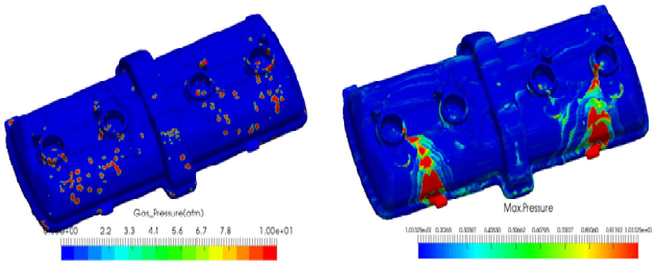

Fig. 4 - The bubbles gas pressure had a good match of the surface defects on the real casting part, also the maximum pressure of the filling process show the gas entrapment history

The good point of the blocked gas mass method is no experience is required from the user, also no need to check the filling process step by step, this is very useful for the fresh engineer to get a reliable result, also help avoid the mistake during result analysis. More ever, this method is very useful for the automatic optimization as a criteria output.

Another example likes the steering post (Fig 6 and Fig 7), due to the complex geometry, the filling process was very complex and gas entrapment is very difficult to avoid. Fig 6 shows the CT scan result and Cast-Designer simulation result includes both shrinkage porosity and the gas porosity result. The gas porosity checked in the blocked gas mass method. The simulation result also matched the real CT result quite well.

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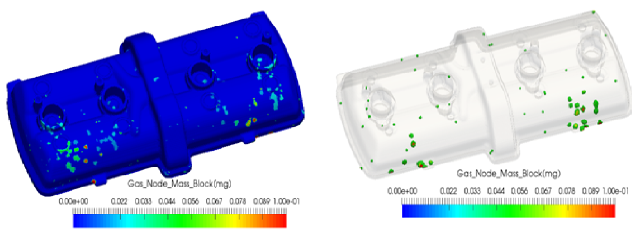

Fig. 5 - The blocked gas mass on the nodes, left: surface and the inside nodes (cause surface defects) right: inside nodes only (cause gas porosity)

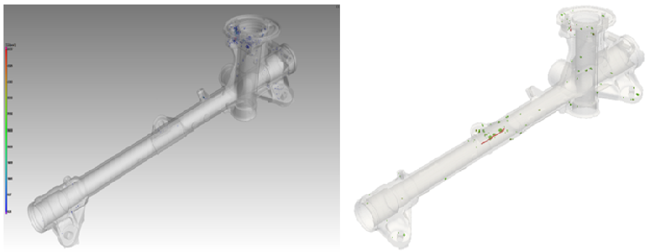

Fig. 6 - View 1, Left: CT result of the steering post to show the porosity inside casting Right: Cast-Designer simulation result of the shrinkage porosity and gas porosity, the red color is shrinkage porosity and green color is the gas porosity

IV. CONCLUSION

A new gas model and Post-Solver has been developed to track the smallest bubbles entrapped into the metal during casting filling, and it has been successfully validated with experimental evidences.

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