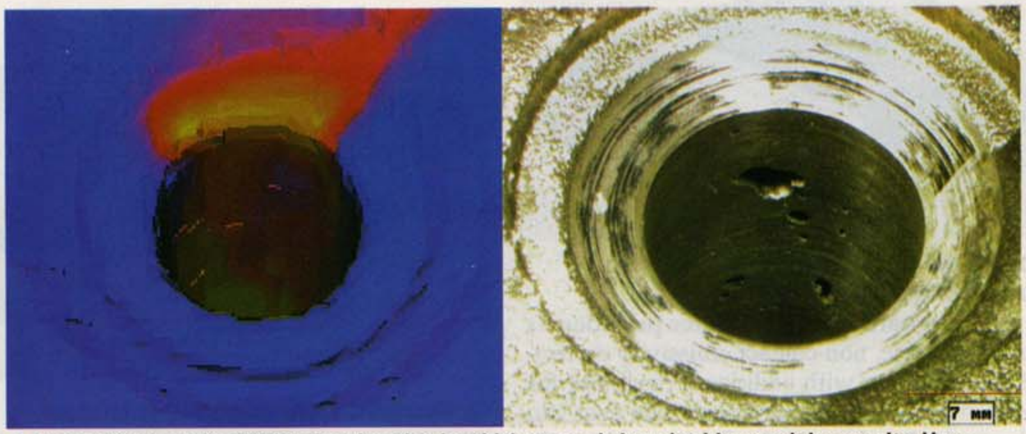


▲ **Casting for rear windshield wiper housing in which trapped air and oxides result in porosity. Here, simulation predictions are compared with the real thing. In simulation, (left), porosity is highlighted in yellow and red. Sound metal is blue.** ***Photos by Flow Science, Inc.***

Virtual reality predicts cast metal flow

And that's not all a versatile computer software system does to help metal casters boost quality and reduce costs.

By FRED L. CHURCH
Editor Emeritus

The computer becomes a *time machine* for casting engineers when it is teamed with FLOW 3-D®, a software program that is marketed by Flow Science, Inc., Los Alamos, New Mexico.

"A time machine?" somebody asked. "How so?"

Well, properly operated in accordance with instructions, the FLOW-3D computer lets the engineers "travel" far enough into the future to actually see how a casting die and its load of molten metal will react to a given set of circumstances and "what if" manipulations.

Armed with information gleaned during this time travel, the engineers can make die design alterations that bypass the costly and time consuming trial and error techniques traditionally used to maximize productivity of casting molds and dies.

Employing computational fluid dynamics (CFD) software, the technology has achieved often spectacular economic and functional benefits in the design, construction and operation of die casting dies for a growing international roster of casters and their customers.

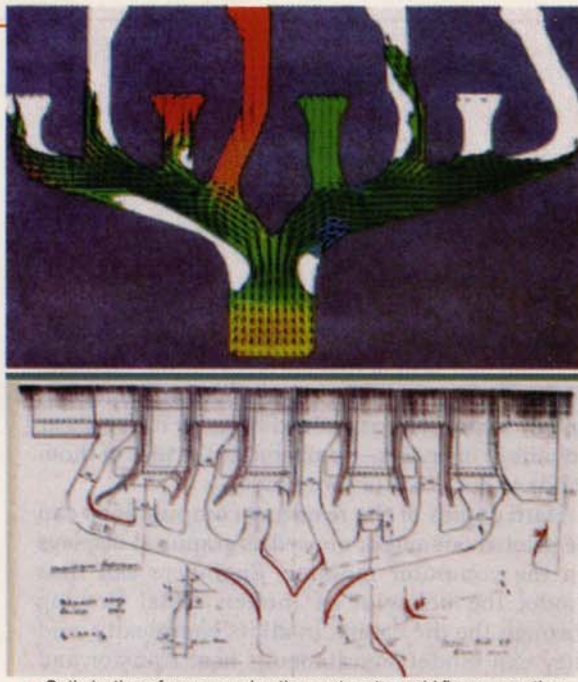
Automakers benefit

The automotive industry, in particular, is reaping benefits with FLOW-3D. "Automobile companies such as GM, Ford, Renault, Fiat and Honda use this software extensively," reports C.W. Hirt, president of Flow Science. "Numerous suppliers also use it, as do die makers and builders of die casting machines."

Alcoa has used the technology extensively for projects such as the development and production of high-quality die castings for the aluminum frame of Audi A8 cars. The resulting components are strong, yet crushable and weldable, according to a paper delivered by Alcoa engineers at an international casting conference.

Quality of high-pressure die castings (HPDC) is a direct function of the amount of gas porosity and nonmetallic inclusions in the cast part. Gas, generated during solidification of molten metal, becomes entrapped in the part, creating porosity that can weaken the structure, cause surface blemishes and hinder weldability of the castings.

Since formation of gas is all but inevitable, the strategy is to deliver it to areas where it will do no harm—namely, overflows that will eventually be trimmed off the cast part and dispatched to the re-



▲ Optimization of runner and gating system to avoid flow separation and air entrapment, and to achieve a balanced flow in all runners.

cycling furnace. The trick is to escort the gas to these overflows before it can become absorbed as porosity bubbles.

At Ford Motor

This is where FLOW-3D comes in. Brad Guthrie, a technical specialist at Ford Motor Co., summed it up neatly:

"Porosity is formed when a flow front breaks apart and traps a volume of air or other gas when the flow front converges back together," he wrote. "Sometimes a single flow front curls over itself, forming a wave eddy."

The resultant porosity can cause blisters in thin-wall castings and result in leakage when machining opens the porous area in the finished part.

In order to expedite the flow of molten metal through the die, a system of runners and gates is incorporated in the design of the die. Using FLOW-3D, engineers can simulate flow patterns in the computer and create a flow path that generates a uniform filling pattern that "sweeps uniformly through the part, pushing all existing and evolving gases in front of it," Guthrie explained. It also cleanses the solidifying metal of oxide inclusions, and forces them into the overflows along with the air and gas.

At Alcoa, use of FLOW-3D helped predict large areas of gas and entrapped air, as well as poor flow distributions, excessive flow breakup and other indications that helped determine die design changes. For the Audi A8 project, FLOW-3D "dramatically reduced proofing time and die rework costs, while optimizing part quality and performance," Flow Science reported.

How it works

FLOW-3D's numerical simulation subdivides the region of the die into volume elements small enough to resolve the smallest die features under consideration. Some of the elements are in the die itself, some in the die cavity.

A set of property values is assigned to each element. (Elements representing molten metal, for example, would be assigned values in temperature, mass, and travel velocity.)

Since time is a factor, time is also subdivided into small intervals so that the solution of a problem can be advanced through elapsed time.

Changes in a single element occur due to flow of metal and heat across surfaces of that element. These changes are easy to compute arithmetically, but a computer is needed because of the sheer volume of elements—numbered in the tens of thousands to hundreds of thousands.

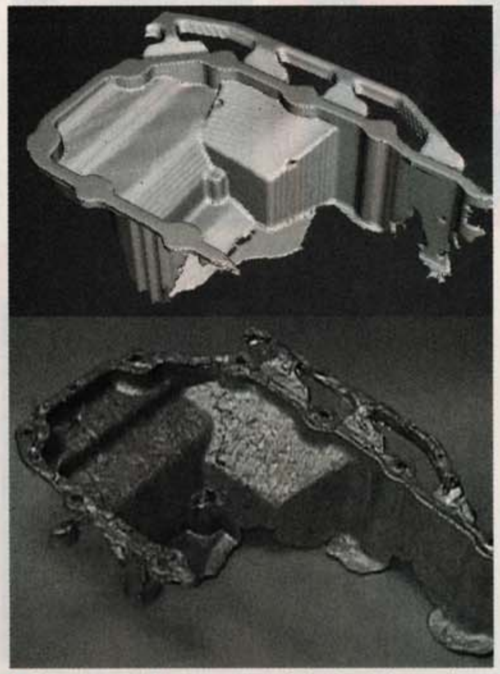
Hard copies of the resulting computations can be printed out and/or viewed as graphical displays on the computer monitor. Engineers can thus model the behavior of molten metal flowing through the die cavity, in all its complexity, and they can model simultaneous heat transfer and metal solidification.

Reap the benefits

As noted above, computer simulation offers numerous benefits. "By first simulating a runner and gating system," a Flow Science publication notes, "it is often possible to remove excess metal from the runner (resulting in less scrap) or modify the system to have the desired flow rate through every gate."

Simulating the filling process yields information about air entrapment and locations where early solidification may occur. It is also possible to predict where structural defects are likely to be located so that reorientation of the part, or a change in venting, or an alteration of pour temperature, may be determined.

The system is also a whiz at tracking defects such as surface contamination (oxides) that are carried by metal flow to remote regions of the mold cavity. This even can be simulated by FLOW-3D, set from a menu in the graphical user interface, and automatically computed during a filling simulation. Relying on post-processing utilities in the program, engineers can examine the probability distribution where such defects are likely to occur.



▲ Oil pan case history compares a filling simulation result with an actual short oil pan casting.

In addition to the requirements outline above, numerical analysis needs a "computational grid" of volume elements that represent the part. Often, heat transfer in the mold must also be included in the computational grid. With FLOW-3D, creation of the grid is automated in the program.

Which metal?

The simulation program also has to include information about the metal (aluminum, zinc, magnesium, etc.) such as density, heat capacity and heat conductivity. Of course, the casting process to be used must be plugged into the program, and solidification modeling calls for information on initial mold temperature, the alloy's heat-of-transformation, and perhaps data on chills and cooling channels.

Interpretation of computed results is the most time consuming task. "Fortunately," Flow Science states, "this is also the most rewarding aspect. Some features such as the last region to fill or location of liquid pockets surrounded by solidified material are easy to locate.

"The greatest rewards, however, often result from a study of small details revealed by simulation. Taking time to look for these details can lead to substantial rewards."

Engineer's best friend

A graphical user environment helps the engineer manage projects, keep track of files, perform cleanup tasks or browse data files. A folder structure guides the user through to define a problem. An on-line help feature is accessed with a mouse click. Data can be displayed in a variety of formats including contour, vector, surface or in tables. The interactive viewer can display three-dimensional shaded surfaces and stereolithography files that define geometry.

FLOW-3D uses simple, easy-to-generate rectangular elements to subdivide the subject being simulated. FAVOR is a special technique that defines geometric regions within the grid. Special numerical, volume-of-fluid (VOF) methods are used to track the location of surfaces and provide accurate representation of surfaces that can coalesce or break apart. Flows are accurately simulated, whether for die casting, gravity casting, spin and tilt casting or low pressure die casting.

How much power?

Flow Science's FLOW-3D can be run on PC or UNIX platforms including IBM, SGI, HP, SUN and DEC systems. Windows NT is recommended for PCs, but Windows 95 and 98 are also supported.

The main number crunching portions of FLOW-3D are written in FORTRAN so that problems of any size may be solved provided there is sufficient memory available in the hardware—roughly 8MB of RAM for every 15,000 control elements. For example, a computer with 64MB RAM could run a simulation having up to 120,000 control elements.

Worldwide, there are over 300 installations of FLOW-3D, company president Hirt explained, but not all of these are for metal casting. It is also used in the plastic injection molding industry. ■

Want more information? Circle number on Reader Service Card.
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