A Deeper Look at Casting Solidification Software

With more choices and capabilities than ever before, this survey of software firms helps engineers evaluate solidification packages.

Len Katzlin
Special to Modern Casting

Under increasing pressure to improve quality and reduce expenses, many foundries are turning to advanced software packages. These software packages help foundry engineers reduce or eliminate the need for trial-and-error prototyping.

Using today's software programs, foundry engineers can model casting variables and identify rigging and mold designs that are likely to cause shrinkage, cold shuts or other defects before any tooling is built, much less any metal poured.

Given the ability to evaluate casting designs through solidification software, the question for many engineers is not whether to use it, but which package best meets the needs for their foundry. Finding the best package, however, isn't easy.

There are dozens of commercial software packages available, ranging from PC-run two-dimensional (2-D) programs to sophisticated three-dimensional (3-D) packages that require the power and performance of a supercomputer.

Selecting through the range of packages and performance capabilities available can be challenging. In general, though, the software can be grouped by price, platform and performance.

Price

Purchase cost is probably the least accurate way to evaluate solidification software because it doesn't account for accuracy and capability. A low-cost software package is a waste of money if it doesn't provide the capabilities required. A high-cost software package is also a waste if its advanced capabilities aren't used.

In addition, foundries should be aware of "hidden" costs. These include costs such as: additional software and

Background: The codes were originally developed 18 years ago by the Atomic Energy Authority of the UK, for nuclear power applications; since then, the codes have undergone 3-4 major rewrites. According to the developer, CFDS codes combine the geometric flexibility of FEM with the physics and solving speed of finite volume methods.

Platforms: Unix-based workstations.

Strengths and Capabilities: CFDS-Flow3D is the only CFD code that has the ability to model multiphase flow, radiation, combustion and free surfaces using a wide range of turbulence models within a multiblock or fully unstructured grid. CFDS-Flow3D and ASTEC allow the importing of fully unstructured grids generated by CAD software such as IDEAS and PATRAN.

Applications: Mold filling, mixing, ladle, ladle/lump flows, solidification, microsegregation and casting.

Cost: $19,050 annual software license for each. No. of installations: 300 worldwide, including Alcoa and Alcan.

Contact: Sales Dept., 412/833-4820; fax 412/833-4850.

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FIDAP 7.0

Fluid Dynamics International
500 Davis St., Suite 600
Evaston, Illinois 60201

Background: The FIDAP code was commercialized and released in 1983. It is a general-purpose finite element code designed to simulate viscous fluid flows, including heat and mass transfer.


Strengths and Capabilities: FIDAP 7.0 is a

To help engineers evaluate the choices being offered, modern casting has described 17 leading solidification packages using information provided by the companies. Additional information can be obtained by circling the Reader Action Card number.

AFS Solidification System
American Foundrymen's Society
505 State St.
Des Plaines, Illinois 60016-8339

Background: AFSolid is a 2-D FDM using conductive heat flow calculations. AFS Solidification System is a 3-D FDM program. Both were developed by Larry Smiley at Reliable Castings Corp.

Platforms: DOS PC (386 or 486).

Strengths and Capabilities: AFSolid combines low cost, relative ease of use and ease of use. Designed to be used on the foundry floor, AFSolid offers a database of casting and mold materials; ability to display cooling plots in color; and ability to display temperature, solidification time and critical fraction solidified plots as color maps.

AFS Solidification System includes a built-in casting and mold material database, and offers complete control of material properties and heat transfer coefficients. Models can use preconstructed tree shapes or files imported via CAD, and simulation setup is straightforward and can be viewed in real time. A variety of graphics and plots can be used to predict shrinkage and hot spots.

Applications: Any casting process.

Cost: AFSolid: $1100 (AFS individual members); $1295 (AFS individual members); $1200 (AFS non-members). AFS Solidification System: $5000 (AFS corporate members); $10,500 (AFS individual members); $18,000 (AFS non-members).

No. of Installations: 375 worldwide.

Contact: David Schmidt, manager of software services; 708/824-0181; fax 708/824-7848.

Circle No. 001 on Reader Action Card.

CAP, AMESH

EKK Computer Modelling and Analysis
2065 W. West Maple, Suite C500
Walled Lake, Michigan 48390

Background: The first version of the CAP finite element casting analysis program was developed by former General Motors programmer Chung-Whie Kim in 1990.

Platforms: DOS PC (386 or 486), Silicon Graphics Workstations.

Strengths and Capabilities: Short time required for analysis execution; efficient use of memory; CAP allows accurate representation of geometry; AMESH mesh generator tailored specifically to casting applications. A post-processor is also available.

Applications: Sand casting, diecasting, permanent mold and EPC. Any alloy or mold material for which thermal properties are known can be used.

Cost: CAP: annual license: $15,000; perpetual license: $45,000.

AMESH: annual license: $10,000; perpetual license: $30,000.

No. of installations: CAP: 5, AMESH: 11.

Contact: Chung-Whie Kim; 810/624-9577; fax 810/624-7158.

Circle No. 002 on Reader Action Card.

CFDS-Flow3D, ASTEC

Computational Fluid Dynamic Services, Inc.
1700 N. Highland Rd., Suite 400
Pittsburgh, Pennsylvania 15221

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hardware that may be required, persons
who may be required to operate the
software, technical support and software
upgrades to provide additional capa-

tilities or handle additional casting pro-
cesses. Before purchasing or leasing any
software, foundry engineers should de-
determine how that package will fit into
their current and future operations.

platform

The software packages surveyed
in this article run on three types of plat-
forms: DOS-based, 386 or 486 personal
computers (PCs), Unix-based worksta-

tions and supercomputers. Each has its
own advantages, and some companies
offer the same product for both high
performance machines and PCs.

PCs are the most affordable, but may
not provide the computational or vis-
ualization performance needed to take
full advantage of the software.

Workstations made by Silicon Graph-

ics, Inc., Sun Corp., Hewlett-Packard,
Digital Equipment Corp. and IBM pro-
vide the performance, but at a moder-
ately expensive price.

The supercomputers made by com-
panies like Cray are among the most
powerful and the most expensive sys-
tems available.

Performance

The actual run-time needed to model
an application depends on the com-
puter, software and complexity of the
application. Generally, workstations
are much faster than the PCs, while
supercomputers are much faster than
workstations. However, if a PC model
may achieve a usable result faster than
a workstation model, even though the
workstation is "faster." Some compa-

nies use a supercomputer to perform
intense computation and output the
data to a workstation for visualization.

This slide shows Rapid/Cast's main menu
layout, visualization of temperature pro-
file and cooling curves from the casting
simulation program.

This FIDAP results plot illustrates the
temperature contours of a wheel casting
as it cools.

This Solstar program shows the predicted
shrinkage in this stainless steel valve
casting.

RMI-based code that features FGEN
interactive geometry-based modeling build-
ing module, RHIC boundary and condition
module, FSTOLY module to solve both transient and steady-state
problems, FSTOLY for 2D and 3D visualization.
FIDAP also features mouse-driven opera-
tion with menus, forms, multiple windows and a
context-sensitive, on-line help capability.

Applications: Casting solidification and
and cooling convection. Currently used to model
casting with phase change, temperature jumps
across gaps; Hail-Herculex cell analysis; convec-
tion in tundishes; and aluminum extrusion.

Cost: Workstation license: $16,000 per year;
PC license: $1215 per year.

MAGMASOFT, Inc. 

15701 Sorrento Valley Blvd. 

Bayona, CA 92037 

USA 

Contact: Ken Trimble, manager, sales & mar-

Circle No. 004 on Reader Action Card.

Flow 3-D

Flow Science, Inc.

1325 Trinity Drive

Los Alamos, New Mexico 87544

Background: Flow 3-D is based on method-
ology developed at the Los Alamos National
Laboratory. Since its 1980 release, the program
has evolved with additions for a wide assort-
ment of physical models, advanced numerical
techniques and powerful pre- and post-
processing features.

Platforms: Alphanumeric workstations

and minicomputers, and 486 PCs.

Strengths and Capabilities: Flow 3-D offers
modeling capabilities for all types of discrete
and continuous casting processes. The program
performs fully coupled filling solidification and
shrinkage analysis or studies individual pro-

cesses. Known for its accuracy and realism, users
like it because it requires no complicated mesh
generation or the setting of sensitive convergence
parameters. Pre- and postprocessors, including
a solids modeler, are fully integrated. The program
employs a finite control volume method using
easily generated rectangular grids. Geometries are
embedded in the grid using the FAVOR tech-
nique, which eliminates "stair step" inaccuracies
and provides extra transfer areas; free surfaces
are modeled by the VOF method, with accurate free-
surface boundary conditions.

Applications: All casting processes, includ-
ing phenomena associated with such items as
filters and inserts for making composites.

Cost: Workstation annual lease: $12,000;
mainframe annual lease: $20,000; perpetual
source code license: $55,000.

No. of Installations: 100 worldwide.

Contact: Flow Science, Inc.; 505/662-2036; 
fax 505/662-6564.

Circle No. 005 on Reader Action Card.

MAGMAsoft

Magna Foundry Technologies, Inc.

2903 S. Arlington Heights Rd.

Arlington Heights, Illinois 60005

Background: Developed by foundrymen at
the Technical University of Aachen, Germany,
the Technical University of Copenhagen, Den-
mark, and MACMA GmbH, Aachen, Germany.

MAGMAsoft is an advanced 3D fluid flow and
heat flow simulation package based on both
FDM and FEM.

Platforms: Unibased systems.

Strengths and Capabilities: It features
modules designed to project management,
pre-processing, fluid dynamics and heat
flow processing, post-processing, and
thermophysical data collection. Its capabilities
include a powerful flow solver for fluid flow
problems such as in-mold and cold shots; di-
rect visualization of problem areas; ability to run
multiple cycles in permanent mold and die-
casting applications; ability to quickly model
complex castings such as cylinder heads.

Recently released modules and capabilities in-
clude a low-pressure die casting module, a cast
iron module and residual stress analysis.

Applications: Sand casting, permanent mold
casting, LPDC and tilt pouring for steels,
grey and ductile iron, aluminum, and zinc,
copper and nickel-based alloys.

Cost: $59,000; License: $450/month.

No. of Installations: 120 worldwide, in-
cluding GM, Ford, Mercedes-Benz, BAW, Mazda
and Fiat.

Contact: Lothar Kallen, president, 709/447-
1001; fax 709/447-0901.

Circle No. 006 on Reader Action Card.

Mavis, Diana

Eldown Software Ltd.

The Abbey

Hensington Park

Swansea

West Glamorgan, England SA2 8PP

Background: Mavis and Diana are 3-D so-
lidification simulation packages. Both contain
two types of simulators, a rapid simulator and a
finite difference model. Diana is for low-
and high-pressure die casting processes. Mavis is
for gravity casting processes. Both packages
were developed at the IRC for Materials in High
Pressure Applications at the University College of Swansea, U.K.

Platforms: DOS PC (386 or 486).

Strengths and Capabilities: The packages
are extremely user friendly. They contain solid
modeling facilities and a variety of color graphi-
In terms of evaluating performance, there are several subcategories to look at, including preprocessing capabilities, calculations, post-processing capabilities, ease of use, visualization and support.

Preprocessing—Choices include 2-D or 3-D representation. A 3-D representation can provide more detail and insight, while 2-D software is less expensive. Some software packages are designed to receive geometry from a customer, eliminating the need for solid modeling. Other software programs contain built-in geometry modeling tools, while others use commercially available CAD software.

Another issue is whether the software uses finite element method (FEM), finite difference method (FDM) or an empirical (geometric) method. Complex shapes can more easily be described using the FEM, but it typically takes longer to run. Empirical based software is fast, although not as accurate as software using either FDM or FEM.

Solutions—All software packages model solidification—they just do it in different ways. Empirical-based software packages use approximate calculations, as well as turbulence. Many are beginning to offer solidification kinetics (micromodeling) capabilities. Some can transfer that information to commercially available stress analysis software packages.

Post-processing—Most packages feature built-in post-processors. Output includes 2-D and 3-D color-coded contour maps of freezing times, temperature fields, Niiyama coefficients and x-ray plots of likely defect locations/hot spots. Simulators are either Cell or CFD—first order and simulation times without the need for property data. FDM—processes the advantages of all numerical analysis. Geometrical shapes can be imported from CAD systems.

Applications: Any casting process.
Cost: Approximately $14,000 each.
No. of Installations: 15 (Europe).
Contact: Edawn Software; (0792) 295389; fax (0752) 295771.

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**Phoenics-2**

Phoenics North America

A div of Concentration, Heat and Momentum Ltd. (CHAM)
P.O. Box 7574
Atlanta, Georgia 30357

Background: The Phoenics (Parabolc, Hypocyclic or Elliptical Numerical Integration Code Series) suite of computational fluid dynamical codes was developed in the early 1970s by D. Brian Spalding at Imperial College, London, England. In 1981, it became the first commercial general purpose 2-D and 3-D CFD code. Phoenics was originally designed to model turbulent fluid combustion; it includes the ability to simulate heat transfer and convection of heated fluids.

Platforms: DOS (380/486) PCs, Unisys-based workstations, supercomputers.

Strengths and Capabilities: Finite volume method enables use of new Phoenics code on a smaller system while still getting the same results as on a larger system. It allows users to examine solidification over a range of temperatures; take into account the effects of turbulence, buoyancy, convection and inclusion; model macro and micro properties; and perform free surface studies.

Applications: Modeling, intrusion and continuous casting.
Cost: PCs, $10,000; Workstation: $20,000; Supercomputers: $50,000, 64 supernodes.
No. of Installations: 12, including Alcan, Asea, Concast and Nippon Steel.
Contact: Pedro Marcal, president; 404/351-3709; fax 404/351-6388.

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**ProCal**

UES Inc.

175 Admiral Cochrane Drive, Suite 110
Annapolis, Maryland 21401

Background: The original release performed conduction heat transfer analysis of expanding radiation capabilities and was aimed at investment casters. Full Navier-Stokes flow with free surfaces was added for permanent mold modeling. In subsequent years, ProCal has grown to include microstructure modeling, stress analysis, and electromagnetic and automatic meshing.

Platforms: PCs and engineering workstations running Unix, Convex, Cray.

Strengths and Capabilities: Using FEM, ProCal solves fully coupled thermal flow, electromagnetic problems. It accounts for trapped gas, vents, sand permeability and burnout patterns. Nonlinear stress can be modeled along with thermal and mechanical contact at material interfaces. Micromodeling is also included for providing detailed information about microstructure and mechanical properties. The user-friendly, menu-based interface contains databases, automatic mesh generation capabilities and sophisticated visualization tools.

Applications: Sand, permanent mold, low and high-pressure die, structural investment, single-crystal investment, continuous, centrifugal, tilt pouring, EPC and iron casting in all alloys.
Cost: Initial fees ranging from $5000-$150,000. Software may be purchased.
No. of Installations: 80.
Contact: Mark Samonds, director; 410/573-2037; fax 410/573-2041.

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**Rapid/Cast**

Mountain Top Technologies Inc.
415 Schoolhouse Road
Johnstown, Pennsylvania 15904-5717

Background: Developed by Concurrent Technologies Corp. for the Navy under the National Center for Excellence in Metallurgical Technology Program, Rapid/Cast is based on an enhanced version of the SOLAVOC code. CTC enhanced the code with advanced visualization tools, solidification kinetics and defect prediction criteria, and it applied it to a range of casting processes.

Platforms: Silicon Graphics Indigo and Indigo2 Workstations running IRIX 4.x.

Strengths and Capabilities: Rapid/Cast provides a complete suite of analyses, ranging from modulus calculations based on Chvoronov's rules and section modules for quick approximation to comprehensive and fully coupled fluid flow, heat transfer and solidification kinetics calculations for detailed evaluations. Highly interactive, it provides the unique ability to change the properties of individual cells through the mouse controlled user interface and consists of six modules.

Applications: Rapid/Cast can analyze a number of different castings, ranging from a
Some provide the ability to use commercially available packages, such as PATRAN, ANSYS or ABAQUS. Advanced solidification software not only models hot spots, but other defects such as microporosity and differences in alloy concentration.

Ease of Use—Several packages are designed for use without extensive training by engineers on the foundry floor. Software packages with more sophisticated capabilities often require more specialized training. Advanced ease-of-use capabilities include: built-in, complete materials database, pull-down menus, "soft" buttons (on the screen) instead of keyboard commands and point-and-click mouse operations.

Visualization—Basic solidification software can show temperature, solidification time and critical fraction solidified as 2-D color maps. Advanced software packages offer 3-D capabilities, animation, interactive object slicing, a variety of shading options, full color adjustment, and the ability to visualize transient and nontransient data, including modulus, macroporosity, microporosity, dendritic solidification, grain size, turbulence and shrinkage by different criteria.

The FLOW 3D system shows the solid fraction contours in midplane of a sand mold about halfway through complete solidification of this iron casting.

In this Swift application, a 3-D model is analyzed, searching for areas of potential hot spots.

The AFS Solidification System (3D) automatically creates a meshed model of casting, core and risers.

Support—All software companies provide documentation. Other types of support may include: on-site training seminars, telephone/fax support, bulletin boards and direct computer links, worldwide user groups and various consulting and engineering services. Some firms tailor their software programs for specific applications.

By comparing the features and capabilities with their budgets and needs, foundry engineers can find the right software package for their requirements.

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10,000 lb nickel-aluminum bronze marine casting ing to aluminum silicon automotive pistons to airframe components made out of a titanium-aluminum metal matrix composite.

Cost: $50,000 (first copy); $27,500 (second copy) and $13,750 (all subsequent copies).

No. of Installations: 2.
Contact: David G. Wink, president, 814/260-3013.

Swift
JRL Research, Inc.
5713 Crabapple Lane
Madison, Wisconsin 53711-3474

Background: Swift is based on the Chvojnov’s nodal method concept for solidification modeling. The fundamental nodal concept was expanded to account for locations within the casting and in the mold material. The nodal approach requires only construction of a conformal mesh for the casting.

Platforms: UNIX workstations, D3S386/80/66/40.

Strengths and Capabilities: Swift allows for analysis in four different modes and features a database of casting and mold materials. The user can specify the type of metal and mold material. Later, foundry engineers can change the casting fill temperature (to simulate the effect of superheat on freezing order), the mold and ambient temperature, mold saturation temperature and other process variables. It provides for modeling chillers, insulators and riser castings that can be placed on the casting.

The program also allows the solidification front wave analysis technique to be applied to the mold material. In this case, the contours describe the healing of the mold material as time progresses (possible local saturation of the core(s). All simulations are performed through a menu-driven interface with interactive response time. Visual graphic presentations illustrate the effects of multiple changes in design and/or process variables.

Applications: Sand molding, shell molding and investment castings.

Cost: $12,000 for the first year, PC platforms: $3,000 for the first year.

Contact: Louis Salter, 814/257-2524. Fax 600/270-015.

No. of Installations: 20.

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**The Flow 3D System shows the solid fraction contours in midplane of a sand mold about halfway through complete solidification of this iron casting.**

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