

On-line Casting Doctors – On Call for Anyone, Anytime, Anywhere

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Abstract

Less than 2% of foundries use CAD and simulation tools despite proven benefits of quality, cost and productivity improvements. The barriers – high capital investment, computer skills and technical support – can be overcome with an innovative approach borrowed from telemedicine. The patient (foundry) with a problem (defective casting) approaches a primary health center (CAD center). The local consultant generates test data (casting model), sends the data to a specialist doctor (simulation expert), passes the diagnosis/advice back to the patient and supervises the treatment. We envisage a network of casting 'health centers' manned by local foundry consultants, with Internet links to casting simulation experts. Each center may be set up by a foundry cooperative, local engineering college or professional organization. Three different implementation models were investigated, based on the distance and type of communication link between the participants: co-location, asynchronous and synchronous. Using this approach, the entire process – starting from a foundry engineer approaching a local center to receiving the final results – can be completed in much less time and cost compared to shop-floor trials.

Keywords: Casting, CAD/CAM, Internet, Process Simulation, Telemedicine.

1 Introduction

Computer-aided casting design and simulation technology is well established today. It has evolved over nearly three decades: starting from text-based methoding calculation programs of 1980s, progressing to 3D casting simulation programs of 1990s and leading to the current era of intelligent casting design and analysis programs [1]. There are proven benefits: both short term (quality assurance, higher yield and faster development) and long term (better image, confidence and competitive edge). Through continuous improvements, the programs have become significantly more user-friendly, reliable and affordable than their earlier versions.

The key steps in computer-aided design and simulation of a typical casting are illustrated in Figure 1. First, a solid model of the cast product has to be created from its drawing, using a 3D CAD program. The same CAD program (or a special-purpose casting design program) can be used for converting the product

model to a casting model (by adding feeders, gating system, draft, allowances, etc.). The casting model is then imported into the simulation program for analyzing mold filling and casting solidification. Based on the results of simulation, the casting design (and sometimes, the product design) may be modified and simulated again until satisfactory results are obtained (defect-free casting and optimal yield). Further steps could include NC machining or rapid prototyping of patterns and automated inspection using coordinate measuring machine (CMM). The solid model provides the backbone for integrating all the above tasks, leading to higher geometric fidelity (between the designed part and final casting) and significantly reduced lead-time.

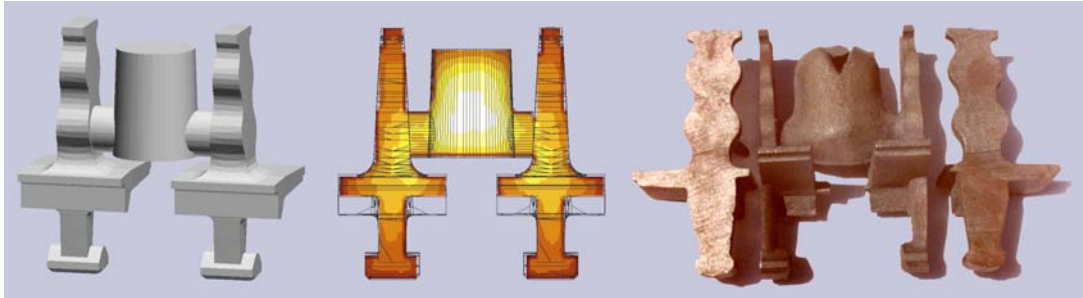


Figure 1. Ductile iron insert (from left to right): casting model, solidification simulation, cut sections of casting.

Yet, despite the advances and benefits, it is estimated that less than 2% of foundries worldwide use CAD and simulation technology. Most of these are large foundries. Others are effectively left with little or no access to the technology as before, because of the following reasons:

- *High implementation cost:* the total cost of appropriate computer hardware, peripherals, CAD and simulation software, system integration, database customizing and annual maintenance is prohibitive for small foundries.
- *Qualified manpower:* foundries find it difficult to attract and retain qualified engineers to work on the software programs owing to the significant difference in salary and working environment compared to other sectors.
- *Local technical support:* the software firms are usually based in cities and find it difficult to provide technical support for small foundries in rural areas, especially with the present quality of travel and communication links.

To overcome the above barriers, a step-by-step explore-adopt-adapt-integrate strategy and cooperative ventures have been suggested [2]. Even these measures are proving difficult to implement in a long-drawn critical transition period that finds most small and medium size foundries struggling to survive.

The rapid growth of Internet technology was expected to enable easier access to customers, faster business-to-business transactions and reduced costs (raw materials, overheads, inventory, etc.) [3]. This was fuelled by the emergence of several 'dot-com' ventures for engineering and even casting-specific applications. But many of these appear to be less than effective, because they did not foresee the need for educating potential end-users and for adopting an integrated 'brick+click' strategy, both of which require extensive resources.

There is thus an increasing gap between requirement and fulfillment with respect to CAD/simulation technology, particularly for small and medium enterprise (SME) foundries. According to the latest survey of foundries worldwide, there are 5000 units in India [4]. By a conservative estimate, more than 80% of these are SME foundries relying mainly on jobbing orders. Their rejections at casting and machining stages continues to be very high (often more than 10%), coupled with poor yields and long development time. On the other hand, there appear to be less than ten organizations providing casting design and simulation solutions (software programs and/or consulting services). Geographical and cultural barriers between rural foundries and city-based software vendors/consultants further contribute to the gap.

A similar problem exists in the health domain. Patients in rural areas do not have a convenient and cost-effective access to specialist consultants in urban areas. To bridge this gap, a new technology called *telemedicine* has gradually emerged over the last four decades, with rapid progress in late 1990s. After a brief overview of this technology, we will present a similar system for casting.

2 Telemedicine

Telemedicine has been defined as “the use of electronic information and communications technologies to provide and support health care when distance separates the participants” [5]. A more general definition encompasses not only health care, but also education, information and administrative services that can be transmitted over distances using telecommunications technologies. Types of data include text, auditory verbal notes, still images, short video clips and full-motion video. Transmission devices include telephone, radio, facsimile, video link and Internet modem. It may be conducted in real time (like video conferencing) or asynchronously (say, e-mail).

The most common telemedicine system comprises of computer-based video conferencing devices placed at remote rural clinics and an urban specialist center, linked by digital telephone lines. It allows the specialist consultants to communicate with patients as well as the primary care providers in an interactive environment. The systems may be configured in different ways, ranging from a single source of referrals (for example, a rural community hospital) and a single source of consultants (such as an academic medical center) to complex ‘hub-and-spoke’ networks involving many referring and consulting facilities.

Telemedicine technology may be used for routine consultation, preventive medicine, public health, patient education and management of chronic conditions. Earliest applications were reported as early as 1960s, and these were tested in medical schools, state hospitals, airports, jails, nursing homes, peace-keeping missions and recently even in space shuttles. Almost every clinical specialty has used telemedicine in some way, though the most widely reported applications have been for radiology, cardiology, dermatology and psychiatry.

Several studies have been carried out to establish the benefits and effectiveness (including cost-effectiveness) of telemedicine. A recent review covering over 1000 such studies states that the general benefits include (1) enhancing the quality and efficiency of health care, and (2) increasing the fairness and equality of the

distribution of services, mainly in remote areas [6]. Telemedicine helps in reducing the number of patient transfers to hospital and adverse events during transfer. It also increases the number of therapeutic measures before transfer is undertaken. For example, a particular study (mentioned in the above review) found that 72% of patients scheduled for hospital admission showed normal results of tele-echocardiography tests and did not require admission. Ambulances having telemedicine links with hospitals could carry out pre-hospital diagnosis 25 minutes in advance, saving valuable time after admission. The social benefits in bridging the healthcare gap between the country and the city, and in enabling patients in remote areas to stay close to their family under times of stress are well recognized by all involved. Most of the studies showed that the quality of consultation through telemedicine technology is comparable to conventional (face-to-face) practice. The major cost benefits are by avoidance of patient transportation and better utilization of expert consultants' time. It has however, been pointed out that a break-even number of telemedicine consultations need to be achieved to offset the cost of acquiring and implementing the system.

3 Online Casting 'Doctors'

Telemedicine has been enthusiastically embraced in countries such as Australia and Canada where medical costs are high, ratio of expert doctors to patients is low and distance between them is large. This has motivated us to explore a similar approach for the casting domain. The goal is to develop a system for bringing the casting 'doctors' online and make them accessible to any 'patient' irrespective of time and distance barriers.

3.1 CAD and Simulation Centers

The proposed system (referred to as CAST-Ex-Net) has a modular architecture that can be easily duplicated or expanded (Figure 2). The simplest configuration comprises of one or more 'CAD Centers' connected to a 'Simulation Center' through the Internet. The CAD Centers are set up in remote areas where several foundries are located. These can be established by a local engineering college, training institute, professional organization or even a cooperative venture of foundries. The basic facility at a CAD Center includes a Pentium computer with Windows operating system and a solid modeling program (such as CATIA, Cimatron, Delcam, Mechanical Desktop, Inventor, I-DEAS, IronCAD, Pro-Engineer, SolidWorks, Solid Edge and Unigraphics). A single engineer with previous experience in casting (preferably in methoding and tool development activities) and trained in solid modeling can handle the center and interact with the end-users.

The Simulation Centers can be established by experts in casting design and simulation. Academic and research institutions as well as casting simulation vendors can take the lead. The minimal facility will comprise of a casting simulation program installed on a high-end computer with Windows or Unix operating system (see Appendix). The expert must be knowledgeable in casting process as well as simulation theory and is expected to have a Masters or higher degree in related areas. Depending on the area of interest of the experts, each Simulation Center can develop its own area of specialization, for example, investment casting of alloy steel castings or pressure diecasting of magnesium alloy castings.

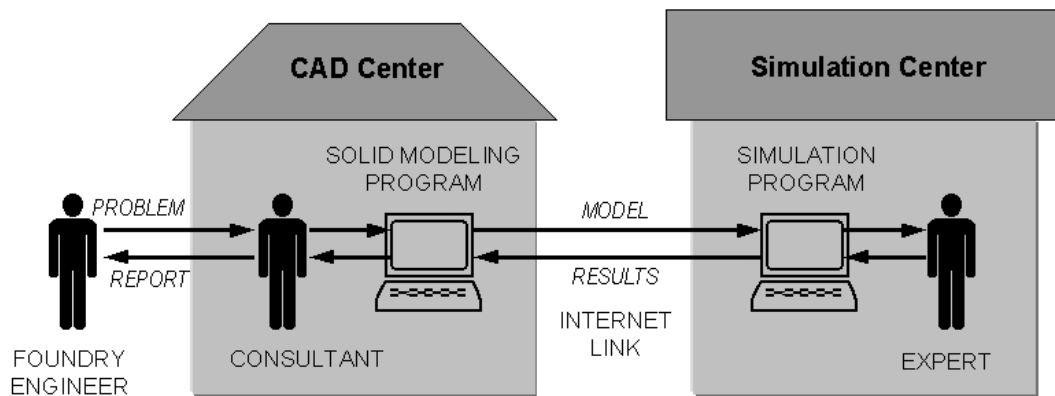


Figure 2. Simulation expertise accessed at local CAD centers through Internet.

3.2 Step-by-Step Procedure

The simplified step-by-step procedure for providing casting design and simulation service using currently available technology is described below.

1. The end-user (foundry engineer) approaches the local CAD Center with a problem casting (that is defective or has low yield) or a new casting (that has to be quickly developed for a customer). He provides the following inputs to the CAD Engineer:
 - (a) Drawing of the casting (with all allowances) in paper or digital format (ex. image or AutoCAD file).
 - (b) Composition and properties of the cast metal and mold material (also cores and feedaids, if any).
 - (c) Methoding details (casting orientation, parting line, location and dimensions of feeding and gating system and pouring temperature).
 - (d) Description of the current problem (nature, location and size of defects, and yield) and main requirement (defect elimination or yield optimization).
 - (e) Sample castings with cut sections or photographs showing defects, if any.
2. The CAD Engineer creates a solid model of the casting, converts all other inputs to digital format (photographs can be digitized using a scanner), crosschecks all the information and sends it to the nearest or appropriate Simulation Center. If the file size is small, it can be sent through e-mail. Otherwise, it can be uploaded to an Internet site and a short e-mail message is sent to inform about its location. To reduce file size as well as ensure security, the input files can be compressed into password-protected files before transfer. The password can be sent separately to the person receiving the inputs.
3. The Simulation Expert receives the above inputs, studies them, pre-processes the simulation program (importing the casting model, specifying material properties and process parameters, and setting up boundary conditions) and carries out mold filling and casting solidification analysis. If several casting layouts are provided or if the feeder sizes have to be

optimized, then each layout is simulated. A report of the results of analysis (mainly color-coded pictures showing metal flow and solidification patterns) along with a summary and recommendations, is prepared by the expert and sent back to the local CAD Center.

4. The CAD Engineer receives the results, prints a hard copy and hands over the report to the foundry for implementation.

3.3 Benefits

The total time for completing the entire procedure, starting from an end-user approaching a CAD Center to receiving the final report, depends on the following factors:

- Casting complexity (reflected by geometric features and model file size)
- Completeness and correctness of other input information (material and process)
- Solid modeling skills and simulation expertise available
- Number of casting layouts to be analyzed (different feeding/gating systems)
- Power of computer hardware (mainly CPU speed and RAM)
- Communication bandwidth available for data transfer
- Human delays between different steps in the procedure.

The most time-consuming step is the creation of solid model, which can take less than one hour for a simple valve casting to several days for an automobile engine block. Once the solid model is complete, creating and simulating a casting layout can usually be completed in a single day. Thus a medium complexity casting can be optimized within a working week: two days for receiving all inputs, solid modeling and sending the data to the simulation expert; three days for simulating 2-3 layouts, creating the report and sending the report back; and one day for handing over the report to end-user.

Virtual trials save the material, energy and labor resources otherwise consumed for shop-floor trials (pattern modification, molding, pouring, cleaning and inspection). These usually take a working week per layout – most new castings require at least 3-4 trials over a period of one month or more. Also, simulation usually provides a better insight into the process and enables the casting to be optimized with a sufficient margin of safety (with respect to process parameters), thereby avoiding sudden and unexpected increase in rejections at casting or machining stage.

The consultants and experts will gradually gain experience with the technology, fine-tune the system, streamline the procedures and find new applications such as standardizing the methoding for a particular class of castings (characterized by shape, metal, process, quality and quantity) and determining the core competence of a particular foundry.

4 Implementation Models

We have investigated three approaches for implementing the above concept, depending on the level of interaction required between the participants: the foundry, CAD Center and Simulation Center (Figure 3). The level of interaction

in turn depends on the location of the participants and the type of communication link between them. The models are described below, along with industrial examples for illustration purpose.

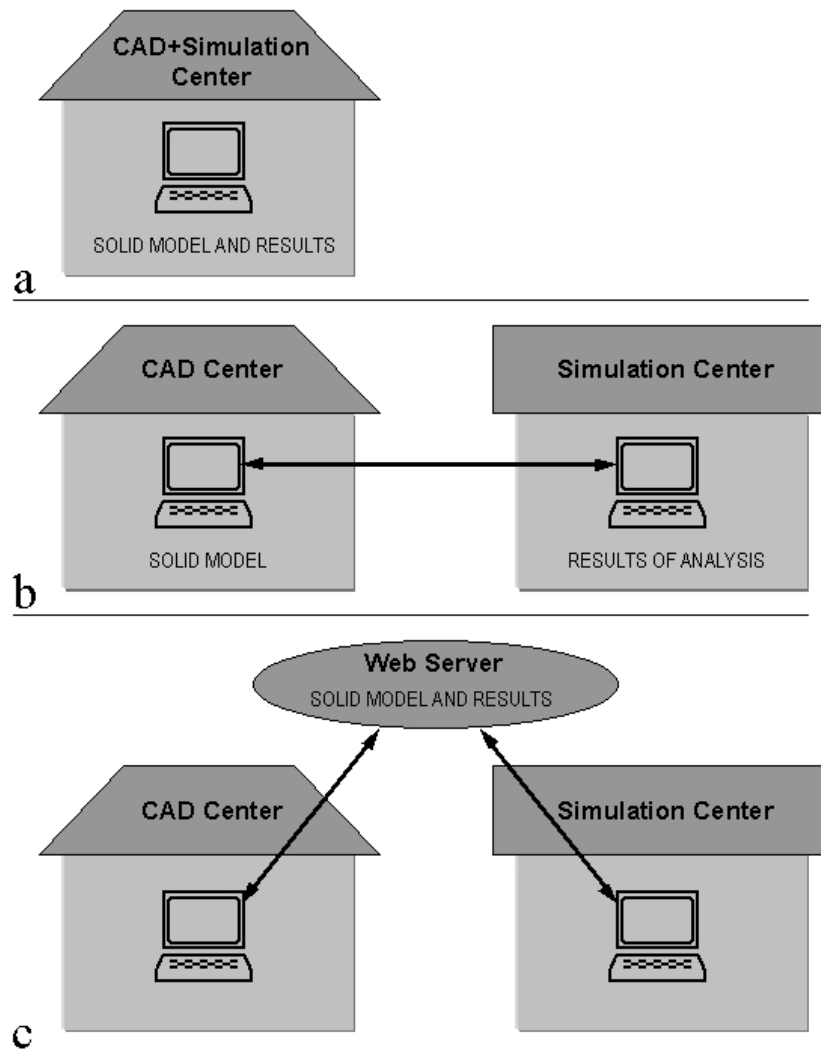


Figure 3. Types of interaction: (a) co-location, (b) asynchronous, (c) synchronous

4.1 Co-located Interaction

This is the simplest approach in which CAD and simulation programs are installed in a single computer or on two computers co-located in the same premises connected by a direct link. The foundry engineer brings his casting drawing and other inputs to the CAD/simulation engineer, who prepares the solid model, transfers it to the simulation program, analyzes the casting and prepares the report. This approach is useful if all the tasks are performed by the same engineer, or if CAD engineer and simulation expert belong to a single organization located close to an area of foundry concentration.

This approach has been implemented at Hyderabad by the local chapter of the Institute of Indian Foundrymen, with an initial grant from the Government of

Andhra Pradesh and support from the Software Technology Parks of India. It is expected to benefit SME foundries in the state, most of which are concentrated near Hyderabad. More than ten local foundries became initial members of the center for using the facilities on an hourly rate basis.

4.2 Asynchronous Interaction

In this approach, the CAD Center and Simulation Center are located in different places. Both have e-mail facilities for contacting each other, as well as for transferring input data and output results. In general, the CAD Center is located close to the end-users. If the end-user also has e-mail facility, then the results can be sent directly.

This approach has been tried out with our lab in IIT Bombay acting as the Simulation Center, connected to CAD Centers through e-mail link. In one of the earliest case study using this approach, a ductile iron insert casting (shown in Figure 1) produced at Kulkarni Engineering Associates Ltd., Sangli, Maharashtra, was solid modeled by a CAD company in Pune and sent by e-mail to the Simulation Center for analysis. Since the foundry already had an e-mail facility, the results could be sent to the foundry directly.

4.3 Synchronous Interaction

In this approach, a network of CAD and simulation centers are connected by Internet and have facilities for integrated data management and automation of routine tasks. It requires all three participants – the foundry, CAD Center and Simulation Center – to have stable and high bandwidth links to the Internet.

The screenshot shows a web browser window with the URL http://www.metalcastingworld.com/cadcast/rfq_form.php?login=pqrs&sessionid=4636035321&is_buyer=buyers. The page title is 'METALCASTINGWORLD' and the main heading is 'CONSULTING PROJECT - PROJECT DETAILS'. The form is divided into two main sections: 'Account Information' and 'Casting Details'. Under 'Account Information', the 'Company Name' is 'Pqrs Ltd' and 'Your name' is 'Patel'. The 'Casting Details' section contains several input fields: 'Part Name' is 'Differential_Casing', 'Part Type' is 'Automobile', 'Part Weight' is '4.2 kg', 'Part Metal' is 'Ductile Iron', 'Wall Thickness' has a 'Minimum' of '4 mm' and a 'Maximum' of '23 mm', 'Casting Process' is 'Sand casting', 'Parting' is 'horizontal', 'Mold' has 'Length' of '450 mm' and 'Width' of '400 mm', 'Cope' has 'Height' of '150 mm', and 'Height of Casting' has 'In Cope' of '75 mm' and 'In Drag' of '75 mm'.

Figure 4. Online form for providing casting project information.

This approach was initially tested at metalcastingworld.com web site and then the technology was transferred to Jyoti Web Technologies Pvt. Ltd., Vadodara for implementation at their casting portal clickafoundry.com. It is mainly meant for, but not limited to, casting suppliers of Jyoti Ltd. In the initial version of the

system, an end-user logs into the web site (using a login name and password), provides all required inputs using online forms and uploads the casting drawing (Figure 4). An e-mail is automatically generated and sent to the CAD Engineer, who downloads the drawing, prepares the solid model and uploads it to the web site. Again, an automatic e-mail alerts the Simulation Expert, who downloads all inputs, completes the analysis and uploads the report. The end-user logs into the site again and downloads the report.

An advanced version of the synchronous interaction model is currently being developed. It is named WebICE for Web-based Integrated Casting Engineering (Figure 5). The system allows all participants to simultaneously access the casting project data, as well as execute simple functions (such as cost estimation) online. A library of material properties and process characteristics has been developed to eliminate the need for manual input, the source of many errors. In addition, a special algorithm compresses the solid model files to less than 5% of their original size (reducing the need for high bandwidth Internet connection). Another algorithm decompresses the models and displays them to the user with rotation and zoom facilities. Any foundry user, irrespective of their location, can access the system at any time using a standard Windows computer and an Internet Browser (such as Microsoft Internet Explorer or Netscape Navigator) that is either free or inexpensive.

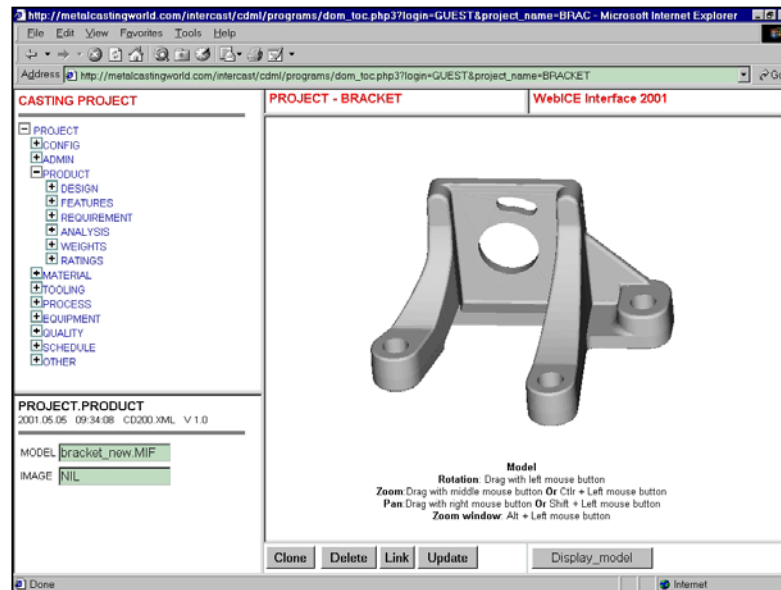


Figure 5. User interface of web-based integrated casting engineering (WebICE)

5 Conclusion

This work demonstrates the feasibility of applying the concept of telemedicine, which makes specialist health care accessible for rural patients, to the casting domain. The basic configuration (comprising of CAD Centers in foundry concentration areas connected to Simulation Centers through the Internet) can be easily duplicated and expanded to create a network of such centers, each with a unique specialization depending on local needs and capabilities. Various technologies and methodologies involved, including casting design, process

simulation, results interpretation, optimization, user input standardization, data transfer mechanisms, routine tasks' automation (such as e-mail notification), file security and web-based project management have been developed over the last few years and tested by taking up industrial case studies. Other researchers and industry participants are urged to test the system, carry out independent techno-economic studies and take the initiative to implement similar systems. We strongly feel that this approach will integrate foundries, local institutions, consultants and experts into a close-knit community that will share domain knowledge for mutual benefit and success in a globally competitive arena.

Acknowledgements

Several individuals and organizations provided the motivation and help to investigate the ideas described in this paper. This includes Rahul and Anant Amin of Jyoti Ltd., Vadodara; Prabha and Prakash Kulkarni of Kulkarni Engineering Associates Ltd., Sangli; Dr. Sheila Bhide (AP Government) and Dr. S. Sundarrajan (DRDO), Hyderabad; M.R. Shah of Foundry Magazine, Ahmedabad and R.T. Kulkarni of Arkey Conference Service Cell, Pune. The work of our Ph.D. student Milind Akarte on WebICE system and M.Tech. student Jayesh Gokhale for the model compression/display algorithm is acknowledged. Finally, the author would like to thank the Institute of Indian Foundrymen for providing the opportunity and a platform to share the ideas with fellow researchers and practicing engineers.

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Appendix

Casting Simulation Programs

Software	Developer/Vendor	Indian Representative
AutoCAST	Advanced Reasoning Tech. Pvt. Ltd. Vashi, New Mumbai 400703, INDIA Tel: (+91-22) 782 2262 Fax: (+91-22) 782 2262 E-mail: info@adva-reason.com Web: www.adva-reason.com	Contact the developer/vendor
CAP/WRAFTS	EKK, Inc. 100 North Pond Drive Suite A Walled Lake, MI 48930, USA Tel: (248) 624-9957 Fax: (248) 624-9957 E-mail: ekk@ekkin.com Web: www.ekkin.com	Contact the developer/vendor
CASTCAE	CT-Castech Inc. Oy Tekniikantie 21 B, P.O. Box 524 02151 Espoo, FINLAND Tel: (+358) 9 2517 5353 Fax: (+358) 9 2517 5354 E-mail: sales@castech.fi Web: www.castech.fi	Usha (India) Ltd. (Process Automation Division) 12/1, Mathura Road, Fadidabad 121003, Haryana Tel: (129) 274754 / 274751 / 271623 Fax: (129) 277679 E-mail: uilpad@nde.vsnl.net.in
CASTFLOW, CASTHERM	Walkington Engineering, Inc. AUSTRALIA Tel: 1-800-397-1859 Fax: 1-608-873-5579 E-mail: billw@walkengr.com Web: www.walkengr.com	Contact the developer/vendor
FLOW-3D	Flow Science, Inc. 683 Harkle Rd, Suite A, Santa Fe, NM 87505, USA Tel: (505) 982 0088 Fax: (505) 982 5551 E-mail: cfd@flow3d.com Web: www.flow3d.com	Frech Far East Ltd. 401 Golden Gate Comm. Bldg., 136-138 Austin Road, T.S.T., Kowloon, Hong Kong. Tel: (852) 27210690 Fax: (852) 23141720 E-mail: Frechfareast@aol.com
JSCAST	Komatsu Soft Ltd., Engg. Solution Dept., Business Div. 2 3-1-1, Ueno Hirakata-city, Osaka 573-1011, JAPAN Tel: (+81 72) 848 1739 Fax: (+81 72) 849 4009 E-mail: cae@komatusoft.co.jp Web: www.komatusoft.co.jp	Contact the developer/vendor
MAGMASoft	MAGMA GmbH Kackertstr. 11, 52072 Aachen, GERMANY Tel: (+49-241) 889 010 Fax: (+49-241) 889 0160 E-mail: info@magmasoft.de Web: www.magmasoft.com	Magma India Liaison office C-8, Nagarguna, 504, Paiga Plaza, Basheer Bagh, Hyderabad 500063. Tel: (40) 666 8570. Fax: (40) 666 8569 E-mail: magma_india@vsnl.net
MAVIS	Alphacast Software Ltd. Swansea, UK Tel: (+44-1604) 674 716 Fax: (+44-1604) 660 476 E-mail: sales@alphacast-software.co.uk Web: www.alphacast-software.co.uk	Vision Technologies 114-A, St No 2, Guru Teg Bhadur Nagar, Chandigarh Road, Ludhiana Tel: (98141) 61780 Fax: (161) 493972

NOVASOLID, NOVAFLOW	NovaCast AB Soft Center, S-372 25 Ronneby, SWEDEN Tel: (+46-457) 386 300 Fax: (+46-457) 156 22 E-mail: info@novacast.se	Contact the developer/vendor
PAM-CAST/ SIMULOR	ESI Group 6, rue Hamelin, BP 2008-16 75761 Paris Cedex 16 FRANCE Tel: (+33-153) 651 414 Fax: (+33-153) 651 412 E-mail: info@esi-group.com Web: www.esi-group.com	Benchmark Engineering Systems Kayem Executive Chambers S-3, 2nd floor, Gem Plaza 66 Infantry Road, Bangalore 560001 Tel: (80) 559 9201 / 559 6100 Fax: (80) 559 9082
ProCAST	UES Software Inc. 175 Admiral Cochrane Drive, Suite 110 Annapolis, MD 21401, USA Tel: (410) 573 2037 Fax: (410) 573 2041 E-mail: sales@ues-software.com Web: www.ues-software.com	Advanced Forming Technology Center 326, 8th Main, 3rd Stage, 4th Block Basaveshwarnagar, Bangalore 560079 Tel: (80) 323 7487 Fax: (80) 323 7427 E-mail: mail@advancedforming.com
RAPID/CAST	Concurrent Technologies Corp. NCEMT, CTC Drive, Johnstown, PA 15904, USA Tel: (814) 269 2886 Fax: (814) 269 6480 E-mail: ncent-info@ctc.com Web: www.ncent.ctc.com	Contact the developer/vendor
SIMTEC	RWP Gmbh Am Munsterwald 11, D-52159 Roetgen, GERMANY Tel: (+49-2471) 123 00 Fax: (+49-2471) 123 099 E-mail: simtec.gundlach@t-online.de Web: www.simtec-inc.com	Contact the developer/vendor
SOLIDCast (previously AFSolid)	Finite Solutions, Inc. 1015 N Mitchel Av., Arlington Heights, IL 60004, USA Tel: (847) 398 5162 Fax: (847) 398 5179 E-mail: FiniteIL@aol.com	EDS Technologies Pvt. Ltd. 153, 2 nd Cross, Promenade Road Frazer Town, Bangalore 560005 Tel: (80) 551 4338 / 339 / 609 Fax: (80) 551 4328 / 530 9104 E-mail: edsblr@edstechnologies.com Web: www.edstechnologies.com