Computers in Foundries

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ABSTRACT

Computers have now entered into the foundry engineering. Foundry mechanization and modernization are of considerable importance today when the foundry has evolved from an ancient art into a modern science and it is fully controlled and monitored by computers. Modernization is the only key to improve casting quality and productivity. From industrial point of view, they have been in use in the administrative areas of finance, accounting, personnel records, wage, salaries, and inventory control for a long period. Many foundry machine systems are computerized. Due to the entry of computers in foundries, fatigue and strain on the workers and staffs have been considerably reduced during working and work culture has improved tremendously. Improved work culture can lead to a sense of participation, involvement, and creativity. This review paper discusses on the role, prospects, and application of computers in foundries. Besides, an introduction on the computer aided foundry model design and computer aided foundry die design are presented precisely in this paper. It also discusses on the numerical simulation of casting solidification performed in foundries and a brief information about the computerized and automated foundry line have been provided in this technical paper. The applications of expert systems in foundries and various types of foundry software packages commonly used in the metal casting industries are explained in detail in this review paper.

RIASSUNTO

I computer sono entrati prepotentemente nella fonderia, un'arte antica che si è evoluta in una scienza moderna. La fonderia è oggi completamente monitorata e controllata dal computer, che assume un'importanza primaria per migliorare la qualità dei getti e la produttività. Dal punto di vista industriale, i PC sono da tempo utilizzati nelle aree amministrative della finanza, contabilità, gestione del personale, salari, stipendi, gestione del magazzino. Attualmente molti sistemi di macchine per fonderia sono computerizzati. Grazie al computer la fatica e lo stress per i lavoratori e lo staff si sono ridotti notevolmente. La cultura del lavoro è notevolmente migliorata, e con essa si sono sviluppati il coinvolgimento, la creatività e il senso di partecipazione. Questo articolo di rassegna presenta ruolo, prospettive e applicazioni del computer nella fonderia; in particolare si sofferma sulla progettazione degli stampi, sulla simulazione numerica del complesso processo di solidificazione e sulle linee di produzione computerizzate e automatizzate. Vengono infine prospettate le applicazioni dei sistemi esperti e son passati in rassegna vari tipi di pacchetti software comunemente adottati nella fonderia.

KEYWORDS

Computer aided foundry model, Computer aided foundry die-design, casting design and numerical simulation, foundry expert systems, foundry software packages.

INTRODUCTION

Foundry technology deals with the processes of producing castings in molds made in either sand or some other material. Metal casting is the oldest manufacturing processes. Today, a variety of molding processes and melting equipment are available to cast different types of metals and alloys in foundries. However, the methods and techniques of production of castings have changed considerably, the fundamental principles remain almost the same. Castings have several characteristics that clearly define their role in modern equipment used for transportation, communication, power, agriculture, construction and in industry. Cast metals are required in various shapes and sizes and in large quantities for making machines and tools, which in turn work to provide all necessities and comforts of life. However, certain advantages inherent in castings such as design and metallurgical advantages and in the casting process itself, endow them with superiority over other manufacturing methods. Foundry mechanization and modernization are of considerable importance today when the foundry has evolved from an ancient art into a modern science. Computers have entered into all industrial applications, and more so in foundry technology [1, 4].

II. PROSPECTS

Nowadays, casting quality is considered as an important one. This satisfies the customer requirements in many ways. To achieve and maintain quality, it is necessary to control the production process firstly. Manual control does not fulfill to attain the expected quality of castings. So, computers are introduced to manage and control the process efficiently. Application of computers plays a vital role to control the entire casting process, quality, metal composition, liquid metal handling, and to perform casting defect analysis with the aid of expert systems. Besides, computers help to simulate the casting solidification during processing. This paves the way to design the casting correctly and hence to avoid major defects like hot spots and also to identify and locate the stress concentration zones. It provides the temperature history of castings, detailed information on the temperature contours, and distribution inside the solidifying casting can be understood. At present, different types of software packages are available to perform analysis on various aspects.

Among them, finite element analysis is an important tool to study the temperature, the stress distribution and micro structural evolution. Modern foundries are automated and absolutely controlled by computers with minimal manual assistance. Pollution and emission in foundries are monitored and controlled by computers. Computers with the aid of imaging systems perform micro structural characterization and capture photomicrographs since software is available in them [2, 4].

III. COMPUTER AIDED FOUNDRY MODELS DESIGN

The traditional approach to resolve the design and the process planning tasks, commonly used in a foundry, is that the plans are handed over to the experts who specify the procedures to make the cast product and draw it. The designers, using their experience and knowledge, generate projects and instructions for manufacturing the foundry products based on the design specifications and the available installations and operators [1]. Consistent designing and planning require knowledge of casting processes and experience. This has led to the development of Computer Aided Process Planning (CAPP) systems, which are becoming more and more important in this field. CAPP systems are beginning to be developed as a link between design and manufacturing, filling the existing gap between CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing). CAPP allows the user to develop an integrated structure that deals with the flow of information between CAD, CAPP, MRP and numeric control (NC) activities within the company [2,3]. There are two approaches to computer-aided process planning. The first is the variant approach, in which a new process plan is generated using existing standard process plans stored in the database. The second is the generative approach, in which a new process plan is generated from scratch, i.e. it will not use any standard existing process plan. The basic requirement for a generative process planning system is to interpret the given component model drawing in terms of manufacturable features. The main objective is the realization of a computer-aided system to help, automatically select and finally define the parameters of a foundry models. In the applied methodology, the steps are divided into three parts: knowledge acquisition, the activity modification and finally development and implementation of the tool [2-4].

Foundries represent an important sector of the casting manufacturing industry. One of the most important aspects is the designing of the models with their equipment. The successful casting of a pre-designed shape is heavily dependent on the skill and experience of the foundry engineer and this is a time consuming step in a production environment. Thus, the main objective is the realization of a computer-aided system to define the models parameters as machining allowance, draft corner,

radius, dimension, feed head, flask and pouring system. The software tool used for the prototype system is an object-oriented programming language called Visual Basic, used to create the main functional modules. The computer system starts with the geometrical definition of the part. Based on the geometrical dimensions, the program executes the calculations of the model parameters in order to obtain a correct design. The result gives the parameters for model and a proposal for the dimensions, which can be modified. The main feature of the proposed integrated approach is its ability to handle a variety of components and generate the foundry models for them.

IV. ROLE OF COMPUTERS IN FOUNDRIES

Successfully launching a new cast product into today's competitive market depends on fast, efficient product development, coupled with quick and flexible manufacturing processes. Timing is essential and a delay of a few months can determine loss of market shares and may cause the failure of potentially successful product to fail. Foundries introducing new cast products must achieve a combination of efficient design, concurrent engineering, and just-in-time production. Once a prototype of a new cast product has been market tested, the race is on to deliver it to the market before the competition shows up. Computers have played a major role in expediting time to market for new foundry products. Today's casting designers use sophisticated computer aided design software to create designs on-screen, updating them easily when changes are required. Meanwhile, assembly has become increasingly automated with computerized inventory control systems and assembly robots that can work around the clock and without human error [4].

Casting is the most effective method for producing metal parts, in terms of both material use and labor cost. In comparison to other fabrication methods, casting allows fewer geometrical constraints, a wider variety of alloys, thin walls, and more. However, these advantages can be offset by the long lead-time between purchasing and acceptance, which is a result of the need for a pattern to create the mold. The pattern design process often requires iterative trial and error prototyping since gating design is often based on empirical, mostly undocumented experience. Computers could assist the foundry man in both designing gating and analyzing a design by simulating solidification. In some foundries, the pattern design is made on CAD and then converted to a drawing, which instructs the pattern or die maker. In foundries, the same CAD data created to describe the pattern or mold can be used for simulating the solidification of the molten metal in the ceramic mold.

In recent years, Computer Aided Design has become an essential tool for designing metal parts. CAD eliminates the manual drafting process, and allows the engineer to design more sophisticated parts with greater precision. However, the ultimate output of expensive software and computing power is a two-dimensional paper drawing.

Foundries must interpret the part's design drawing into a pattern design, requiring shrinkage compensation, filleting of sharp corners, and the incorporation of draft angles and parting lines. Such modifications usually require tie foundry to regenerate the CAD file, making the customer CAD file of no use to the foundry. It is easier for the foundry engineer to mark the customer's drawing and forward it to the pattern or mold maker than to redo the CAD [4, 5].

V. COMPUTER AIDED FOUNDRY DIE DESIGN

In the design of casting dies, the objective is to produce sound casting as cheaply and rapidly as possible. At the same time, consideration must be given to suitable die size, locations of gating system, and selection of an appropriate die-casting machine. Foundries in many cases encounter difficulties to ensure shortened lead-time in designing a new die for new product. Much estimation has to be done which use fundamentally based on previous experience and application of various mathematical and empirical equations. Computer programs are developed to estimate main die elements based on the geometry input of casting shape. After initial inputs have been given, the software does full calculations, optimizes selections, and lists main die element sizes. The program can present die characteristics and casting machine characteristics. From both characteristics, the optimum die elements are optimized. Optimum filling time and gating dimensions among other elements of die are determined. Cooling time, cooling channel locations, and flow rates relations are estimated [1, 2, 3].

VI. APPLICATION OF COMPUTERS IN FOUNDRIES

Computers are being used in every field these days and foundries cannot be an exception. In conventional practice, the failure rate of castings is high. Computer simulation minimizes the failure rate to a huge extent compared to manual production. Manual inspection of cast products is quite time

consuming and there will be chances that a worker may not identify a defect. By using sensors, quality inspection may be done very easily and in less time particularly for mass production of castings [4]. Hence, human interference can be eliminated. Application of computers in foundries helps to develop a product directly from an existing product, when no other data on the product like design sketch, material used and others are not available. It also reduces wastage and rejection rate and facilitates continuous research and development. Some of the advantages of computer application are listed below [4].

1. Animation advantage: better imagination and presentation

2. Simulation advantage: predicting complicated outputs like flow of molten metal, possible obstacles, stress and strain, solidification sequence, chances of defects, and complex calculations like stress analysis are done in a fraction of second.

3. Database advantage: facilitates Research and Development. Computer can suggest alternative materials and design options from its inbuilt database to save cost, weight, size, availability, and to vary properties.

4. Communication and networking advantage: better history management, collecting order and feedback, easy interacting with team members, and better customer support.

5. The machine advantage: using simulation Software Packages in foundries. Simulation software's are generally known as CAD/CAM/CAE tools. Some of them are Catia (Computer Aided Three Dimensional Analysis), It is a highly versatile package, which assists in almost all kinds of design such as drawing production, mechanical design, machine parts, sheet metal designing, free style shaper, hybrid design, structural analysis, mold and die casting design, prismatic machining, manufacturing plant layout, and so on. Unigraphics, Solid Edge, Pro E, and iDeas are already developed software packages. IDeas package can optimize design at early stages, which greatly improves product quality while reducing time and cost. Solid Works can create geometry, refine features of a part, make drawings, model trajectories of cutting tools, and develop numeric control. ADAMS is the best package for kinematics and dynamic analysis of mechanical systems. It can predict the behaviors of mechanical systems undergoing large displacement motions. It is used for chain mechanisms and inversions like four bar chains. Ansys is a finite

element package which can handle different types of analysis from linear, non-linear stress and thermal problems to piezoelectric and acoustics. It has some supplementary packages like Ansys Flotrain and Ansys EMag that allow the user to determine the effects of the interaction of stress, temperature, fluid flow, and magnetic phenomena. C-MOLD is a set of integrated CAE simulations for plastic molding process, including injection molding filling, post filling and cooling, part shrinkage, co-injection molding, gas injected molding, reactive molding, blow molding, and thermoforming. Fluent is best suited for fluid dynamics, fluid flow, heat and mass transfer and chemical reaction analysis. Altair Optistruct is a finite element analysis package that can optimize structures to minimize weight, maximize performance using topology, topography, and shape & size. Pro CAST is a casting exclusive software package. Pro Weld is a welding software specific package. Prodigy Plus is a prototype-developing machine with related software and this machine can make prototypes of any complex material. Computers have now become an indispensable tool in every occupation and for all sorts of applications. However, lately, computers have been introduced increasingly for various technological applications, such as drawing and design, process selection and methoding, tooling design, component design, machine design, production planning and control, process control, quality control, and defect analysis. Automation has also come in a big way in foundries and computers have become an essential part of control system for all the automatically operated machines. Robotics has further made their headway into many foundries, which also operate through pre-planned computer programs. In fact, the advent of computers revolutionized the entire structure of foundry by enhancing casting production and productivity, maintaining and improving quality and controlling costs. In casting manufacturing, CNC, CAD, CAM, expert systems and artificial intelligence have further raised the level of advancement. At the present juncture when the demand on the foundry industry to produce castings in large quantities of superior metallurgical quality and to close dimensional accuracy is fast increasing from sophisticated users, specially automobile, aeronautical, electrical, power plant, and machine tool industries. As a consequence it is necessary to consider adopting to consider adopting new technological processes, new materials, and go for automation and

computerization. Computers, though not essential for adoption at every stage of production, hold great promise in ensuring better and consistent quality, higher yields, and lower costs. Computers with the standard as well as specially designed software's have been playing a wide role in the foundry industry. More importantly, their use has been widespread in the following areas [4].

1. Casting design and development for optimum quality, weight, cost, and easy castability.

2. Maintaining pattern designs.

3. Sand control for obtaining desired mold characteristics.

4. Process optimization and selection for ensuring both quality and product costs.

5. Methoding and laying down exact technology of pattern and other foundry tooling design, mold design and die design, gating and risering design, requirement of insulating and exothermic materials, molding, pouring, mold cooling, fettling, and heat treatment.

6. Controlling heat treatment cycles.

7. Production planning and control.

8. Material procurement and selection, Economic order quantity determination for various important items, lead times, reorder points and reserve stocks, ABC analysis, maintaining stock positions of different items of inventory.

9. Deciding chemical composition to obtain desired properties, charge control, melting and melt control.

10. Process control.

11. Quality evaluation, records, inspection, and testing.

12. Cost control at every stage of casting production.

13. Maintaining database for the entire data about production quantities, sand testing, casting production schedules, heat numbers, melt cycles, process controls, quality records, defect analysis reports, and heat treatment cycles in order to maintain quality and achieve easy identification and traceability of products on a long term basis.

14. Maintaining data about calibrations of tools, gauges, instruments, and equipments, corrective actions taken to salvage products, quality records, including quality manual, quality procedures, work instructions, quality plans and quality records.

15. Records about wages and salaries to workers and staffs, labor inputs, incentive schemes, work orders, job evaluation, and merit rating.

16. Maintaining data about daily, weekly, monthly production and productivity.

17. The software is required to operate computers for specific uses consist of the following [4, 5].

18. Operating system, to enable start up, shutting down, performing various administrative functions, such as directory, editing, cut, copy, paste, data transfer and retrieval, saving for future use, and printing or plotting on hard copy.

19. Standard software's, such as those for text writing, publishing, data base management, tabulation, work sheet preparation, drawing, drafting and graphics, preparing slides for presentation, and mathematical calculations.

20. Special purpose software packages, such as those which are designed for specific applications such as gating design and risering techniques, feeding systems for castings, casting and pattern design, inventory control, melt calculations, heat transfer, fluid flow and solidification studies, quality and soundness evaluation.

21. Many of these computer applications are simple: no need to use sophisticated and proprietary software packages. These can be developed in-house by using suitable programming languages, such as BASIC, Pascal, "C", and FORTRAN. Standard software's, such as Excel, D-Base, AutoCAD, Harvard Graphics, Acrobat and Coral can also be used with ease for developing in-house programs. For fast communication, which may be within the foundry industry, within the country or outside the country with overseas casting buyers, suppliers or customers, Internet has now come in a big way as a boon. A large amount of paper work is saved, communication, which took days or weeks to reach from one place to other can now be transmitted and received in a matter of seconds. Sending enquiries to prospective customers, receiving quotations, placing purchase orders, keeping follow-up, having discussions with individuals or a group of people, exchanging technical reports and data, drawings or pictures can all be possible through internet. Foundries can have their own web pages and sites to advertise and publicize their cast products and services and explore markets at a global level [6, 7].

VII. COMPUTER SIMULATION OF CASTING SOLIDIFICATION

Metallurgical phase transformation plays a vital role in the solidification of castings. Casting solidification is the transformation of liquid phase to solid phase with the liberation of latent heat of fusion. During this metallurgical process, it induces casting defects like shrinkage, porosity and hot tears. To eradicate and eliminate these problems, accurate casting design and proper design of gating system is necessary. This can be predicted and designed by means of computer simulation of casting solidification. It helps us to understand the temperature history of the solidifying casting and hence to indentify the hot spot region with the aid of obtained time-temperature contours. Further, it will be used to get defect free as cast products on implementing the above facts attained from the computer simulation process. Since, computers became widely available in industry; researchers have been working on the development of programs to simulate the solidification of castings [8, 11].

Computer simulation of casting solidification of metals and alloys is a complex phenomenon. The assumptions and constraints used for simulation are considered as a vital one. To identify the solidification conditions, simulation of casting process is done by running indigenously developed computer software for the casting process selected for investigation. The program output provides the details on time-temperature profile and heat transfer coefficient values, which plays a key role in the effective design of castings [9].

Many computer simulation programs now exist, but some require computers of a power not generally available to practical foundry men, while others take an unacceptably long time to obtain meaningful results. The aim of computer modeling is to predict the pattern of solidification, indicating where shrinkage cavities and associated defects may arise. Its secondary aim is to provide a choice of quality levels. Besides, it is used to simulate solidification with the casting in various positions, so that the optimum position may be selected. This will help to calculate the volumes and weights of different materials ranges from steel, white cast iron, grey cast iron, ductile cast iron, and non-ferrous metals and alloys in the solid model. It is used to determine the solidification time and behavior of different materials accurately. Hence, it is used to determine the cooling rate influenced by the grain structure of castings. Solidification simulation of castings provides time-temperature data, temperature contours, hot spot locations, degree of recalescence, latent heat of fusion, and solidification time. The obtained time-temperature plot explains the effect of under cooling of solidifying castings which reflects more on the inside microstructures responsible for material properties [9-11].

Casting solidification simulation software program performs firstly, the solid modeling, consecutively, the thermal analysis and solidification simulation. During the simulation process, the effect of varying molding position, ingate position, mold materials, chills, insulating and exothermic materials can be modeled, allowing the optimum method of making the casting to be predicted.

Casting solidification simulation software's are in regular use by aluminium, copper, iron, and steel foundries using processes ranging from green sand, resin and shell-bonded sand to investment and gravity die casting. Applications include large steel castings such as heavy weighing turbine housings, stern frames, critical high-pressure valve castings, repetition castings such as ductile iron crankshafts, where modeling increases the chance of achieving "Right First Time" methoding, so reducing the lead-time for new castings. Foundry method engineers do not only use solidification simulation software's but also casting designers and purchasers are using the software's having experienced significant improved quality from their simulation software-using suppliers [10-11].

VIII. COMPUTERIZED AND AUTOMATED FOUNDRY LINE

A foundry needed to rebuild its automated sand casting line following an accident that damaged or destroyed significant portions of the casting machinery and its control systems. The line needed to be rebuilt quickly so that customers were not lost to competitors and furloughed employees could be brought back to work. In rebuilding the casting line, foundry personnel wanted to ensure that the new controls avoided problems they had experienced with the old control system. Troubleshooting and programming on the old system were hampered by slow response times due to network congestion [2, 3, 10]. Centralized control required that the entire line be shutdown to download software changes or perform routine maintenance. The main interface to the line was through a massive hardwired annunciator panel. Operators were required to follow a multi-step procedure to start up or shut down the line. Some of the benefits are listed below [10].

1. Operators can start the casting line with just a few entries on the touch screen.

2. Alarm lamps have been replaced by color-coded status messages on graphical overview screens pinpointing the cause of problems

3. Changes to the main console can be performed through software changes to the Panel View terminals. No more rewiring the annunciator panel.

4. Common control code shortens the learning time for maintenance and engineering personnel to familiarize themselves with the ladder logic program.

5. Through the Control Logic gateway, maintenance and engineering personnel can monitor, backup and troubleshoot any PLC in the foundry from the comfort of their shop or office.

6. Networking bottlenecks have been eliminated

7. Decentralized control has eliminated the need to shut the entire line down for software modifications or routine maintenance.

IX. EXPERT SYSTEMS FOR FOUNDRIES

Expert systems are a part of computer science in which computers can be made to think like people. In modern foundries, expert systems are mainly used for casting defect analysis. Expert systems are computer programs in which the knowledge and experience of one or more experts is captured and stored to make it widely available. Extracting the knowledge or expertise from the domain expert is an important stage. The knowledge in an expert system may originate from many sources such as textbooks, reports, databases, case studies, empirical data, and personal experience. These systems can be of great assistance in the decision-making process as the computer can be made to think, reason, make inferences and give judgment, conclusions, and solutions to problems. These have wide engineering applications in manufacturing, quality control, casting defect analysis, fault diagnosis, and plant maintenance [4]. In foundries, casting defect analysis is one of the common applications of this system. The entire system consists of an input device like keyboard, a knowledge base, database, inferencing capability, and output device. The knowledge base written in the form of a series of rules contains facts, concepts, and procedures in a form suitable for storage, interpretation, and for matching with the information obtained for a specific problem in the database. During inferencing, the data for the current problem is matched with the knowledge using search and pattern-matching technique and decision or solution, as the case may be is indicated as output. Foundries can buy an expert system shell, so that any desired knowledge can be collected, developed and written into it, and the software is then ready for use. In foundry where many decisions are based on rules of thumb, the expert system can mimic such decision-making and give suitable solutions. Initially, the availability of an expert who is thoroughly familiar with the concerned field of technology is essential to gather knowledge required to develop the expert system. This system once developed can be used as and when required without any further need of the human experts or advisers. Foundries derive much benefit from the expert systems. In foundry, most of the decisions including the defect diagnostics are made because of rules of thumb or heuristics. Some of the potential areas for the development of expert systems in foundries are for diagnosis, and monitoring. Diagnosis expert system can be developed to analyze the defects in castings. It can also be developed in finding a fault in any foundry machinery. Monitoring expert system can be developed to monitor; for example, to monitor the sand mixture properties and give corrective measures for the proper maintenance of sand system [4].

X. FOUNDRY SOFTWARE PACKAGES TO TACKLE TECHNICAL PROBLEMS IN FOUNDRIES

In recent years, key developments have taken place in CAD, casting design, simulation, rapid tooling, intelligent advisory systems, and Internet based foundries and most foundries presently are caught between change and survival. This is especially true in case of the foundries operating in the developing countries. However, they have to keep pace with the changing technological trends, if they have to survive in the global foundry market. If properly adopted, these can lead to both, immediate tangible benefits in terms of shorter lead-time, higher productivity and lower rejections and long term intangible benefits, in terms of better company image, higher confidence, stronger partnerships and improved marketing [4-6]. Casting design involves converting the part design to the tooling design, showing orientation in the mould, parting line, application of draft allowances, gating and feeding systems, core boxes, pattern plates and other elements. Simulation includes mold filling and casting solidification, useful for optimizing the design of gating and risering systems respectively. Casting model is the main input for simulation. Since casting design essentially involves a series of geometric transformations of the part model, the three dimensional CAD systems are used for the purpose. A few programs for deciding the dimensions of feeding and gating systems are available, but these are stand-alone type and cannot be connected to the 3D casting design systems. Currently available software packages for foundry use are listed below [4].

- Magmasoft
- CastCAE
- CastDESIGN
- CastCHECK
- AFS Solid 2000
- NovaFlow
- NovaSolid
- ProCAST
- MeshCAST
- AutoCAST

Magmasoft software offers comprehensive foundry competence, engineering services and powerful simulation tools for the optimization of castings and foundry processes. It is used worldwide and is a highly successful simulation tool for cost effective process layout and prediction of casting quality. Many foundries have adopted this for overcoming the problems in achieving directional solidification. The use of this package can enable quality improvement and cost reduction through robust and optimum methoding of gating and risering, optimization of metal treatment and metallurgy, minimizing of production risks and making best use of all of the cast iron's potential for wide ranging mechanical properties. Further, the microstructure distribution and the local mechanical properties are quantitatively predicted.

CastCAE is a software tool to monitor proper mold filling and simulate the casting solidification coupled with automated risering. It predicts filling patterns, cold shuts, shrinkage and porosity defects reliably.

It is fully based on physical models and is available for all casting processes and metals. It simulates the casting process, revealing the temperature drop and filling order during pouring, followed by the solidification of casting in the mold, where shrinkage and porosity formation during cooling. All the output results will come out as independent files, enabling the user to send the results to those who need to view them, without additional software. It calculates the feeding solution and is more accurate than the traditional modulus and Heuver's circle methods, as it is based on simulation, and thus the alloy and mold effects are taken into account. Cast design uses all three dimensioning rules to determine the proper risers and their locations. Results also include the yield, pouring and casting weights, and suggestions for additional risers if needed. CastCHECK has been used to help in several ways, such as initial design of components, assessment of the feasibility of casting a component, assessment of quality requirements, assessing the proposals to change the design for better castability and inspection by the customer. Solidification simulation using Cast CHECK is used in areas like design of gating and risering, test casting of component and final test castings [4].

AFS Solid 2000 software combines thermal and volumetric calculations to predict shrinkage porosity. The program can installed on multiple machines at one location. The American Foundry men's Society offers a selection of software packages designed specifically for use in foundries are shown below in Table-1[4].

Table-1 Foundry Software Packages from AFS (American Foundry men's Society) [4]

Name of the AFS Foundry Software Package	Description and Application
AFS Gating System	Software for calculating dimensions for a step-down gating system using different types of sprues and runners.
DOEpack	Design of experimental software for optimal product quality.
GAGEpack	A powerful guage calibration tracking software that helps to maintain the history of gauges.
Least Cost Charge	Software used for calculating the least expensive charge mix for alloys with the correct chemistry requirements.
Process Plus	Software used for the creation of useful foundry process control sheets and technical reports.
AFS Risering System	Combines the best of the geometric and modulus risering techniques to predict the best risers for castings.
SQC Pack	Statistical Quality Control Package allows the turning data into useful information.
Weight / Order	A program will calculate the weight of casting based on a material density and casting volume. It also calculates a modulus value, to get an idea about the order of solidification.
AFS Modeling Solidification System 3-D	It is used to predict problems in castings and make changes to the part, risering or process to optimize part manufacture before the first part is made.
R & R Pack	A software designed to provide a complete statistical and graphical analysis of the measurement system.

NovaFlow and NovaSolid foundry packages are applicable to sand casting of grey cast iron, ductile cast iron, steel, aluminium, copper-based alloys, magnesium, lost wax, shell molding, and investment casting of different alloys, permanent mold and high-pressure die casting processes. The main features include advanced algorithms that take gravity and flow into consideration during mold filling and solidification. The common applications have been to optimize the risering requirements, improve yield and reduce time required for cleaning, finishing, and machining castings [4, 9].

ProCAST uses finite element technique and has been adopted for micromodeling, stress, distortion, and automatic meshing. It is also applicable for sand, shell, investment, die-casting, permanent mold and lost foam processes. Foundries have used the software for improving the methoding and simulating the solidification process for producing radiographic quality castings. It can simulate all three primary modes of heat transfer. It also allows the input of thermal, fluid, mechanical, and electromagnetic properties of material as constants or as functions of temperature. It simulates all types of casting processes, solves full three dimension navier stokes fluid flow equations, coordinates rotation for tilt pouring, gas modeling for simulating trapped gas and venting, non-newtonian flow modeling, filter modeling, turbulence modeling, compressible flow modeling, lost foam modeling, and particle tracking. it can also model the injection of gas behind a liquid, providing build-up of pressure driving the flow into the cavity during low-pressure die casting [4,10].

MeshCAST is used for fully automatic 3-D mesh generation and is very convenient for design purposes. It can handle complex geometries, and generates the mesh at a faster rate. It is an automatic 3-D tetrahedral mesh generator. AutoCAST has a knowledge-based system involving large eddy simulation for combining all the three essential tasks, casting design decisions, casting model creation and process simulation. This approach reduces the overhead of importing and exporting data between the systems for each layout iteration, saving not only valuable time, but also the possibility of errors during data transfer [4, 11].

DISCUSSION

Modern foundries are automated and absolutely controlled by computers with minimal manual assistance. Pollution and emission in foundries are monitored and controlled by computers. Computers with the aid of imaging systems perform microstructural characterization and capturing photomicrographs and software is available in it.

The successful casting of a pre-designed shape is heavily dependent on the skill and experience of the foundry engineer and this is a time consuming step in a production environment. Thus, the main objective should be the realization of a computer-aided system to define the models parameters as machining allowance, draft corner, radius, dimension, feed head, flask and pouring system. Computers could assist the foundry man in both designing gating and analyzing a design by simulating solidification. It has played a major role in expediting time-to-market for new foundry products. Computer programs are developed to estimate the main die elements based on the geometry input of casting shape. Optimum filling time and gating dimensions among other elements of die are estimated. Cooling time, cooling channel locations, and flow rates relations are determined. Computers have been introduced increasingly for various technological applications such as drawing and design, process selection and methoding, tooling design, cast component design, machine design, production planning and control, process control, quality control, and casting defect analysis.

Computer assisted casting solidification simulation is used to eliminate defects like shrinkage, porosity and helps to locate and identify the hot spots, consequently reflects on efficient design of components. Besides, it is used to determine the solidification time and behavior of different materials accurately. Hence, it is used to determine the cooling rate influenced by the grain structure of castings. It provides time-temperature data, temperature contours, degree of recalescence, latent heat of fusion and solidification time. Computerized and automated foundry line helps to start the casting line with just a few entries on the touch screen. Alarm lamps are replaced by color-coded status messages on graphical overview screens pinpointing the cause of problems. Through the Control Logic gateway, maintenance and engineering personnel can monitor, backup and troubleshoot any PLC in the foundry from the comfort of their shop or office. Networking bottlenecks have been eliminated. Decentralized control has eliminated the need to shut the entire line down for software modifications or routine maintenance. Application of expert systems in foundries helps in decision-making process. It has a wide range of applications in casting manufacturing, quality control, casting defect analysis, fault diagnosis, and foundry plant maintenance. Foundries can buy an expert system shell, so that any desired knowledge can be gathered, developed and written into it, and the foundry software is then ready for use. Foundry software packages acts as powerful simulation tools for the optimization of castings and foundry processes. It is also a highly successful simulation

tool for cost effective process layout and prediction of casting quality. It can enable quality improvement and cost reduction through robust and optimum methoding of gating and risering, optimization of metal treatment and metallurgy, and minimizing of production risks. Further, the microstructure distribution and local mechanical properties are quantitatively predicted. It functions as a tool for mold filling and solidification simulation coupled with automated risering.

CONCLUSIONS

1. Foundry mechanization and modernization are controlled and monitored by the application of computers.

2. Casting quality and productivity can be enhanced by computerized process control in foundries.

3. Due to the entry of computers in foundries, fatigue and strain on the workers and staffs have been considerably reduced during working and work culture has improved tremendously.

4. Application of computers plays a vital role to control the entire casting process, quality, metal composition, liquid metal handling, and to perform casting defect analysis with the aid of expert systems.

5. Computers help to simulate the casting solidification during processing. This paves the way to design the casting correctly and hence to avoid major defects like hot spots and also to identify and locate the stress concentration zones. It provides the temperature history of castings, detailed information on the temperature contours, and temperature distribution inside the solidifying casting.

6. Different types of foundry software packages are available to perform analysis on various aspects. Among them, finite element analysis is an important tool to study the temperature and stress distribution, and microstructural evolution.

7. Modern foundries are automated and absolutely controlled by computers with minimal manual assistance.

8. Pollution and emission in foundries are monitored and controlled by computers.

9. Computers with the aid of imaging systems perform microstructural characterization and capturing photomicrographs and software is available in it.

10. Computer simulation minimizes the failure rate to a huge extent compared to manual production.

11. In modern foundries, expert systems are mainly used for casting defect analysis and have wide engineering applications in casting manufacturing, quality control, fault diagnosis, and plant maintenance.

12. Foundries can buy an expert system shell, so that any desired knowledge can be collected, developed and written into it, and the software is then ready for use.

13. The use of foundry software packages can enable quality improvement and cost reduction through robust and optimum methoding of gating and risering, optimization of metal treatment and metallurgy, and minimizing of production risks. It also predicts filling patterns, cold shuts, shrinkage and porosity defects reliably.

14. AFS Solid 2000 software combines thermal and volumetric calculations to predict shrinkage porosity.

15. ProCAST uses finite element technique and has been adopted for micromodeling, stress, distortion, and automatic meshing. It is also applicable for sand, shell, investment, die-casting, permanent mold and lost foam processes. Foundries have used the software for improving the methoding and simulating the solidification process for producing radiographic quality castings.

16. MeshCAST foundry software package is used for fully automatic 3-D mesh generation and is very convenient for design purposes. It can handle complex geometries, and generates the mesh at a faster rate. It is an automatic 3-D tetrahedral mesh generator.

17. AutoCAST foundry software package is a knowledge-based system involving large eddy simulation for combining all the three essential tasks, casting design decisions, casting model creation and process simulation. This approach reduces the overhead of importing and exporting data between the systems for each layout iteration, saving not only valuable time, but also the possibility of errors during data transfer.

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