Comparisons of Computer Fluid Dynamic Software Programs applied to Jewelry Investment Casting Process

Somlak Wannarumon, and Marco Actis Grande

***Abstract*—**Computer-based casting simulation as 'virtual casting', it facilitates us to optimize the process parameters to beneficially find out the suitable working model of the casting process. To obtain more precise and realistic solution, the profound understanding in the fundamental concept of simulation software is necessary. This research organized the comparisons of three different simulation software programs: FLOW-3D, ProCAST, and MAGMASoft, which are widely used in industrial casting simulations. This study plays attention in the simulation of the filling step of jewelry investment casting. The experimental simulations, which run in three software programs, were operated by the identical inputs; a same test tree, a same set of material properties including process parameters. The fluid flow inside mould cavities simulated by each software was monitored and analyzed. The results of the study are presented in terms of particular strengths and weakness of different simulation programs and theirs suitability for utilizing in the filling step of jewelry casting.

***Keywords*—**Computer fluid dynamic, Investment casting, Jewelry, Mould filling, Simulation.

I. Introduction

COMPUTER simulation becomes widely used in various applications and accepted in manufacturing as a way to reduce product cycle time and cost. The existing commercial simulation software programs have been developed for various industrial casting applications. Nevertheless, no one provides any modules specifically used for simulating jewelry casting.

Computer-Aided Design (CAD), Computer–Aided Engineering (CAE) and Computational Fluid Dynamics (CFD) applied through software development enables us to simulate casting process similar to real environment as 'virtual laboratory' [1]. Within last decade, computer simulation increasingly plays important role in jewelry investment casting and gradually replaces trial-and-error experiments, which consumes much more in terms of human efforts, costs and times. Several attempts have applied the existing software programs to simulate jewelry investment casting process.

Due to high complexity of jewelry casting process and interactions between liquid alloy and process conditions, computer simulation is as a powerful tool to help us to insight into natural behaviors of the process such as metal flow and turbulence during filling, cooling and solidification of the metal. This leads to better understanding of the mechanisms of defect generations.

Further development in long term goal is to predict casting results and try to prevent casting defects in a reliable method, as a result, reducing production time and cost. The further research tasks of computer simulation of jewelry investment casting are discussed in [2]. One of them is "the study of casting simulation by using different commercially available simulation software packages", which becomes the topic of this study.

Main objectives of the study are to address particular strengths and weakness of different simulation software programs and to allocate the suitable software to simulate in different steps of jewelry investment casting process.

To achieve the main objectives, the sub objectives are to study and compare the important criteria of simulation software packages.

Besides the mentioned objectives, the study aims to better understand the casting process and to comprehend the behaviors of the molten metal during filling.

The paper is organized into five sections. The introduction of the research including its objectives is described in this section. Section II provides the related literature review. The methodology of the research is explained in Section III. The results of the research are discussed in Section IV. The concepts and the results of the research are finally concluded in Section V including the future directions.

II. Literature Review

A. Gold Investment Casting

Investment casting, also well-known called lost wax casting, is considered as a precision casting process to manufacture near-net-shaped metal parts from almost any

S. Wannarumon is with Department of Industrial Engineering, Naresuan University, Phitsanulok, 65000 Thailand. She is now joining the research with Politecnico di Torino Sede di Alessandria, Alessandria, AL 15100, Italy (corresponding author, phone: +39 0131 22 93 00; fax: +39 0131 22 93 99; (e-mail: somlakw@nu.ac.th , somlak.wannarumon@polito.it).

M. Actis Grande is now with Department of Material Sciences and Chemical Engineering, Politecnico di Torino Sede di Alessandria, Alessandria, AL 15100, Italy (e-mail: marco.actis@polito.it).

alloy [3]. The most common use of investment casting recently is the production of components requiring intricate and more complex, frequently thin-wall castings. It could be said that it is one of the most-effective production. From its record, it lies to a great level in the production of art. Investment casting is one of the major methods widely used in the production of gold jewelry. Since this method offers high dimensional accuracy, high-quality of surface finish, and design flexibility [4]. Nowadays, vacuum and high difference pressure between crucible chamber and mould chamber are applied in investment casting to increase the ability of casting small and thin-wall metal parts.

B. *Computational Fluid Dynamics*

Computational fluid dynamics (CFD) is one of the branches of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows [5]. The fundamental basis of any CFD problem is the Navier-Stokes equations, which define any single-phase fluid flow. The most fundamental consideration in CFD is how one treats a continuous fluid in a discretized fashion on a computer. One method is to discretize the spatial domain into small cells to form a volume mesh or grid, and then apply a suitable algorithm to solve the equations of motion. Such a mesh can be either irregular or regular.

Some of the discretization methods [5] being used are:

1) *Finite volume method (FVM).*

This is the standard approach widely used in commercial software and research codes. The governing equations are solved on discrete control volumes. FVM recasts the PDE's (Partial Differential Equations) of the N-S equation in the conservative form and then discretize this equation. This guarantees the conservation of fluxes through a particular control volume. Though the overall solution will be conservative in nature there is no guarantee that it is the actual solution. Moreover this method is sensitive to distorted elements which can prevent convergence if such elements are in critical flow regions.

2) *Finite element method (FEM)*

This method is widely used for structural analysis of solids, but is also applicable to fluids. The FEM formulation requires though special care to ensure a conservative solution. The FEM formulation has been adapted for use with the Navier-Stokes equations. Even though in FEM conservation has to be taken care of, it is much more stable than the FVM approach. Then the new direction of CFD is moving in this way. In general stability and robustness of the solution is better in FEM though for some cases it might take more memory than FVM methods.

3) *Finite difference method (FDM)*

This method is simple to program. It is currently only used in few specialized codes. Modern finite difference codes make use of an embedded boundary for handling complex geometries making these codes highly efficient and accurate.

The Volume-of-Fluid (VOF) method is the most popular and widely used method for mould filling simulation. The reasons are its relative ease of implementation and its basis in volume fractions which lends itself well to incorporation of other physics. The VOF technique is employed by some commercial software packages for casting simulation and analysis, such as FLOW-3D, MAGMASoft, and ProCAST.

FLOW-3D employs finite-difference or finite-volume approximations to numerically solve the fluid and solidification equations. It subdivides the flow region into a mesh of fixed rectangular cells. It is widely used in flow analysis and multi-phase flows [6], [7].

MAGMAsoft employs the finite difference method to solve the heat and mass transfer on a rectangular grid. It is a useful tool for simulating molten metal flow in a permanent mould. It is a comprehensive simulation tool featuring capabilities that show mold filling, solidification, mechanical properties, thermal stresses and distortions, and more for steel, aluminum alloys and Compacted Graphite Iron (CGI). It is widely used in the die casting industry, particularly in foundry applications, for modelling the molten metal flow and solidification in dies [8].

FEM is a broadly used technique to obtain approximate solutions to partial differential equations. The first step of this method is to divide the given problem region into simply-shaped elements creating a mesh. ProCAST is finite-element solver, which works fully on three-dimensional problems and produces tetrahedral meshes [9]. It provides coupled thermal-flow-stress analysis based on the finite element method.

C. *Computer Simulation of Jewelry Investment Casting*

Wright [10] had discussed on the significances and roles of computer simulation in jewelry production. Furthermore, he provided some key directions of the research developments in this area. Computer simulation is classified to two process steps: mould filling and cooling or solidification [11] .

1) *Filling*

Actis Grande *et al.* [1], [12] have studied of the filling times of jewelry investment casting in terms of simulation and experimental verification. They had the several experiments with various types of objects including filigrees. In their researches, FLOW-3D was used for simulating the filling step of the investment casting process.

2) *Solidification*

Fischer-Bühner [2], [11] has applied MAGMASoft to simulate the cooling and solidification phases of the investment casting process. He had proved that computer simulation of jewelry investment casting process could be used as a tool for studying the complex interdependencies during filling and solidification, to design main sprue and feed sprue and to prevent defects and improve quality.

III. Method and Materials

This study extends a part of the research done by Marco Actis Grande *et al.* [1], which had implemented the computer-based simulation to study and analyze filling step of jewellery investment casting. A simplified tree that consists of three various pieces, as shown in Fig. 1, was designed for the experimental simulation. The selection of the studying objects was based on the difficulties in casting: stepped wedge with its variations in part thickness, quad ring with challenging corners, and ball ring with a sphere (one of the most difficult casting shapes). By studying the filling of these pieces, we expect to better understand the filling behavior.

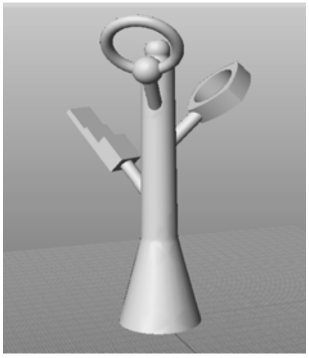


Fig. 1 A simplified test tree used in this study

In this study three simulation software: FLOW-3D, ProCAST and MAGMASoft, were used to simulate mould filling of the investment casting process.

A. Outline of Simulation of Investment Casting

The basic principles of the simulation set-up are the considerations of process parameters and material properties and of how they can be varied to obtain the optimal resulting simulation, which is as much as close to the actual casting. Computer simulation process is typically divided into four main phases:

- Mesh Generation: creating the mesh model of the studying model,
- Pre-processing: setting up the studying model based on physical-thermal-fluid theories,
- Processing: executing the input data and calculating filling, cooling and solidification of the studying model.
- Post-processing: displaying the simulation results and exporting the results in various formats depending on the purposes to be further used.

The following flow chart shown in Fig. 2 illustrates the overall process of implementation of computer simulation of jewelry investment casting. The iterative process was carried out during optimizing the simulation parameters.

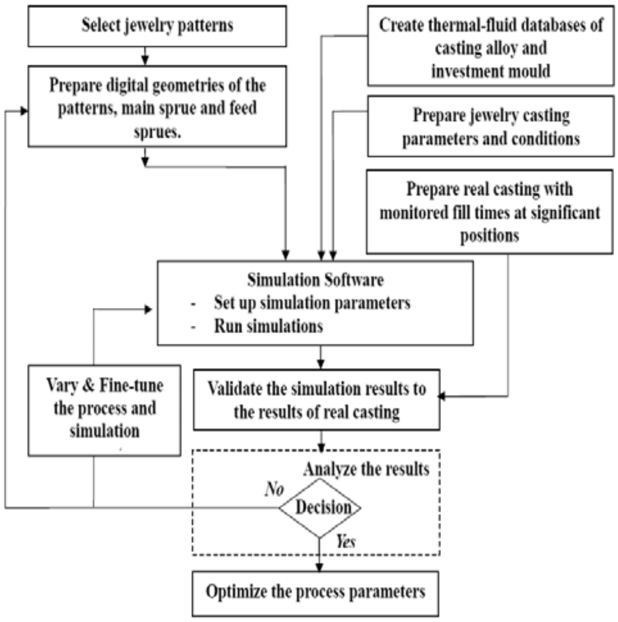


Fig. 2 Overview of computer simulation process applied in jewelry investment casting

B. Jewelry Patterns and Digital Geometries

The preparations of part geometries include jewelry patterns, main sprue, feed sprues, mould, and crucible's nozzle.

.STL file is a common data exchange format that is required as input geometry file of some simulation software program such as FLOW-3D and MAGMASoft. Different software such as ProCAST requires a different method for preparing the input geometry files. ProCAST requires volume mesh models of the casting part and the mould separately.

C. Material Database and Process Parameters

In any simulation software, it generally allows adding or editing a new database of material property; either casting metal or mould material, which will be used in a particular casting process.

In this study, two of material databases were developed and added into the database platform of the software programs. One is casting material: 18K yellow gold alloy; the other is mould material: gypsum-bonded investment.

In setting the simulation of investment casting, the properties of casting are mainly divided into two types: thermal properties and fluid properties. The data of thermal-fluid properties of 18K yellow gold alloy used for the simulation is provided in Fig. 3 and Fig. 4.

For the gypsum-bonded investment, only its thermal properties (as provided in Fig. 5) are required for the simulation.

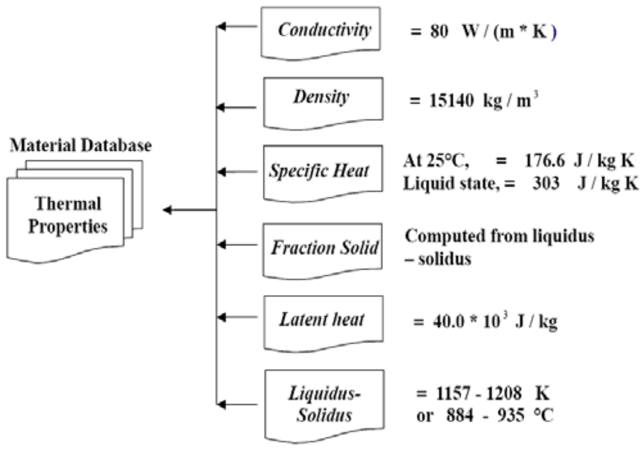


Fig. 3 Thermal properties of casting material (18K yellow gold alloy)

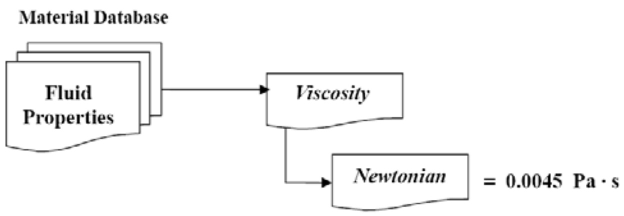


Fig. 4 Fluid properties of casting material (18K yellow gold alloy)

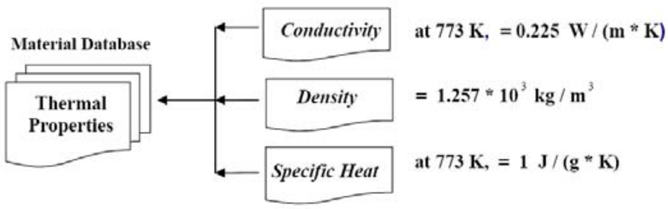


Fig. 5 Thermal properties of mould material (gypsum-boned investment)

The process parameters used in the simulation were based on jewelry casting condition as follows:

- Heat transfer coefficient: 1,000 W / m^2 / K,
- Initial conditions:
  - Flask temperature: 773 K (500 °C)
  - Casting temperature: 1,273 K (1000 °C)
  - Δ Pressure: 30,000 Pa
  - Gravity force: 9.81 m / sec^2

The set-up of simulation run-parameter mainly focuses on the general parameters for computation of flow and thermal parameters.

Flow model used in this study solves the fluid equations during filling, but switch over to thermal only analysis when the fill limit is reached. Filling algorithm used in this case is a free surface algorithm that the momentum contribution is predominant over the mass conservation contribution. The fluid flow is Newtonian flow.

D. *Validation of Simulation Results*

To validate the results of simulation, the real casting of the studied model was prepared. A set of sensors were mounted on the different positions on the model, as illustrated in Fig. 6, to detect the filling times at the different positions in the mould cavities during filling. These detected data would be used to validate the results of the experimental simulations to the results of the real casting.

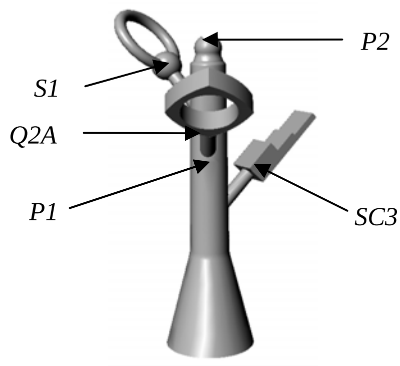


Fig. 6 The sensors were allocated in the different positions of the simplified tree

The identified codes of the locations of the sensors are described as below:

P1 : Middle point of the tree,
P2 : Centre of the round area of the top of the tree,
Q2A : Middle point of the ingate of the squared ring,
S1 : Top of the sphere of the ring,
SC3 : Thick part of the stepped wedge.

The fill times of each position simulated by using the different simulation software would be compared and validated to the fill times detected from the real casting.

The real gold-alloy castings were produced on a vacuum casting machine.

IV. Results and Discussions

A. *Simulation of Jewelry Investment Casting using FLOW-3D*

Actually it is relatively flexible to prepare the parts to use in FLOW-3D. At least FLOW-3D requires .STL format of the casting part, which could be either prepared in only single object or distributed into sub-objects. Furthermore, by using the option 'Complement', FLOW-3D would generate the virtual mould without the request of .STL format of the mould model.

In the preparation of part geometries of this study, we prepared the separating .STL formats of all sub-parts, which would be assembled on the model, as illustrated in Fig.7, including of the crucible nozzle and of the mould, as shown in Fig. 8.

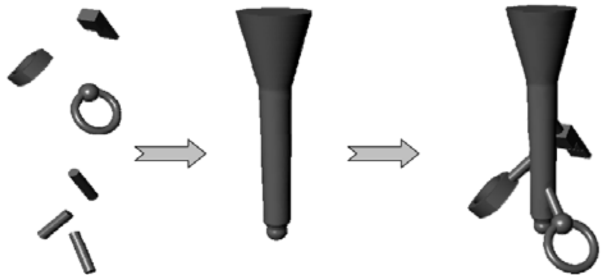
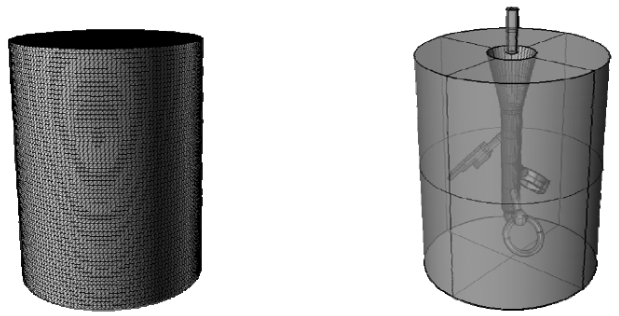


Fig. 7 STL models were prepared separating for tree assembling



(a) (b)

Fig. 8 (a) STL file of mould; (b) Crucible nozzle defined in terms of size and position relative to the main sprue button

All parts were imported into FLOW-3D platform and then set up a mesh block covered on the model, as illustrated in Fig. 9.

Next, the boundary conditions were assigned onto every sides of the mesh block, as shown in Fig. 10. Other works related to setting the process parameters and the calculation parameters.

The resulting simulated filling is provided in Fig. 12. The total fill time of the casting model is 0.338 second. From the results of the simulation using FLOW-3D, the fill times of the five positions were captured and compared with the real casting and the results from other software, as illustrated in Fig. 16, in Section IV-*D*.

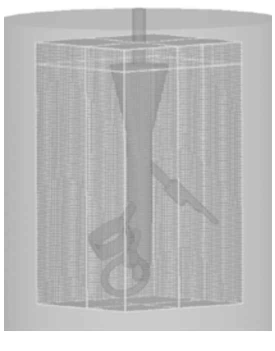


Fig. 9 Single-mesh block set up in FLOW-3D platform

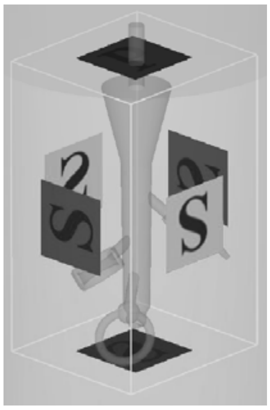


Fig. 10 Boundary conditions set up in FLOW-3D platform

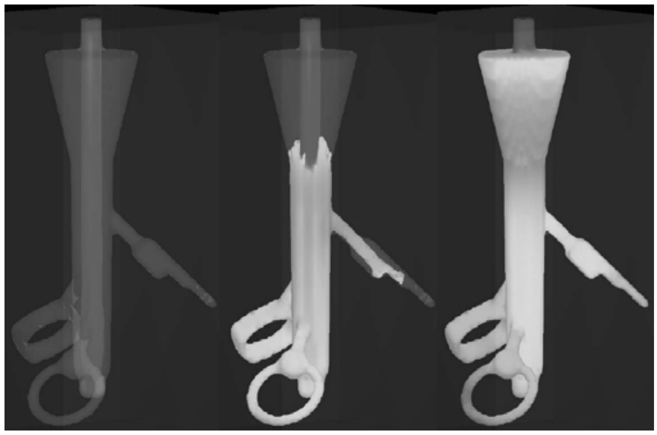


Fig. 11 The simulated filling using FLOW-3D

B. Simulation of Jewelry Investment Casting using ProCAST

The preparation of part geometry in ProCAST differs from in FLOW-3D and MAGMASoft.

Although ProCAST provides MeshCAST module for generating volume meshes including for modification and refinement of mesh quality. PATRAN is needed for generating surface meshes (*.out) of the CAD models. The 'Tet Mesh' (tetrahedral meshing algorithms) of MeshCAST was then used to generate volume meshes of the models. The flowchart of part preparation is illustrated as in Fig. 12.

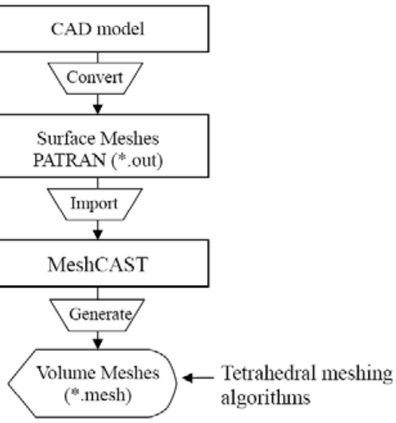


Fig. 12 Overview of the preparation process of volume mesh file (*.mesh)

After the volume-mesh files of the casting parts and of the mould cavity were prepared using the process as illustrated in Fig. 12, then they were loaded into ProCAST platform .

In the material database of ProCAST, two new material types were created. The material properties mentioned in Section III-*C* were input into these new material types. The material types were assigned to the casting part (18K gold alloy) and the mold part (gypsum-bonded investment). Next, the interface between two domains was created to determine heat transfer coefficient onto the interface. The boundary conditions (BC) were created and assigned onto the position of the inlet, where the molten metal would flow inside the mould cavity, illustrated in Fig. 13.

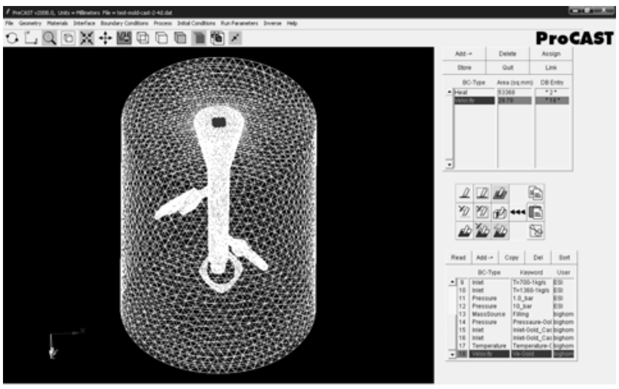


Fig. 13 Boundary condition (velocity type) assigned on to the position of the inlet the model

The process parameters mentioned in Section III-*C* were input into ProCAST platform: process and initial conditions.

Finally, a set of calculation parameters (thermal parameters, flow parameters and general parameters) were specified. Then the set-up simulation was finished and ready for simulation.

The resulting simulated filling is provided in Fig. 14. The total filling time of the casting model is 0.3030 second.

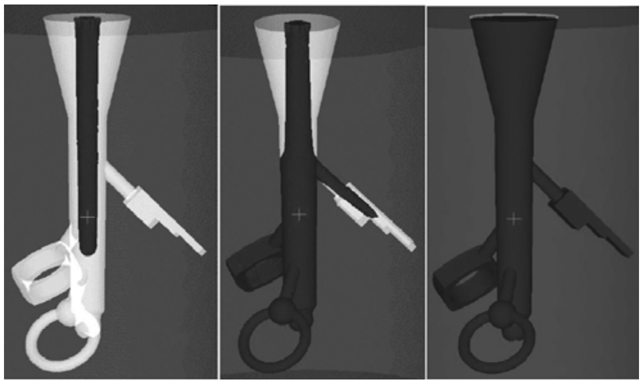


Fig. 14 The simulated filling using ProCAST

From the results of simulation done by using ProCAST, the fill times of the five positions were captured and compared with the real casting and the results from other software, as illustrated in Fig. 16, in Section IV-*D*.

C. Simulation of Jewelry Investment Casting using MAGMASoft

Similar to FLOW-3D, MAGMASoft requires the separating .STL formats of all parts, which would be assembled on the model, including of the crucible’s nozzle and of the mould.

Other data inputs are the same sets of using in FLOW-3D and ProCAST. The resulting simulated filling is provided in Fig. 15. The total filling time of casting the model is 0.3410 second.

Fig. 15 The simulated filling using MAGMASoft

From the results of simulation using MAGMASoft, the fill times of the five positions were captured and compared with the real casting and the results from other software, as illustrated in Fig. 16, in Section IV-*D*.

D. Comparisons of the Results of Simulation from Different Software Program

The comparisons of the results of the simulations of jewelry investment casting by using three CFD simulation software programs in terms of filling times in different positions on the test tree are provided in Fig. 16.

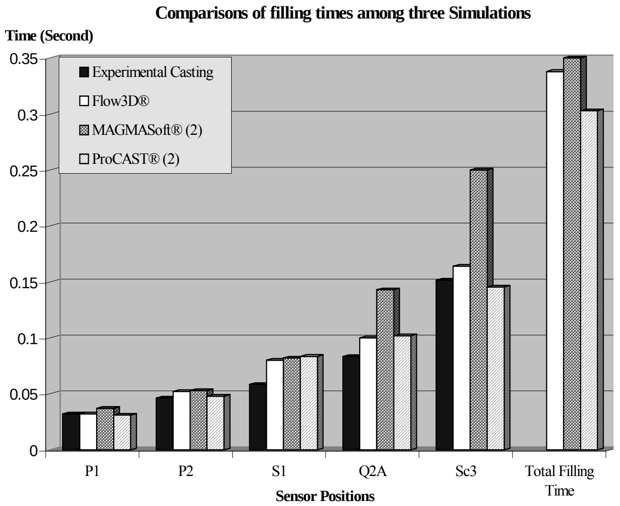


Fig. 16 Comparison of the filling times in five positions on the model

The results of the simulations were compared in terms of the absolute value of the deviation of the simulated filling times from the experimental filling times (|Δ Time|). The comparison results indicate that the average simulated filling times of FLOW-3D and ProCAST are similar with the % of deviation 15.63% and 15.34 % respectively, while the results of MAGMASoft deviate from the real casting about 41.40%.

In the beginning of filling step, the simulated filling times of three software are relatively close to of the experimental casting. But in the filling in the subsequent cavities, they took longer times; as a result, the deviations of filling time are larger. These differences may come from the concept of the pressure difference applied on the inlet in different software, non-linear-flow behavior of the fluid, different mesh generations, and different types and settings of boundary conditions.

Due to the different options of solver, in FLOW-3D, the parallel solver was used for calculating while in ProCAST the general solver was used. Even as the experimental simulations using MAGMASoft are cooperated with Casting Technology Program (CTP), National Metal and Materials Technology Center (MTEC) of Thailand. MAGMASoft works on a computer main station. Therefore, in this study, it could not take the processing time into the account of comparisons among the three software programs.

Referring to the discretization methods, the finite-element method consumes memory space for calculations much less than the finite-difference method.

The quality of meshes is effect to the results of simulation in ProCAST.

Among the advantages of ProCAST in comparison with other simulation software are its capabilities of simulating fluid flow in the fully three-dimensional space and possibility to include model of the mould in the analysis. ProCAST software provides a complete finite element solution that allows for in-depth predictive evaluations of the entire casting process, including mold filling, solidification, micro-structure and thermo-mechanical simulations.

TABLE I
COMPARISONS OF THREE CFD SIMULATION SOFTWARE

Simulation Software	FLOW-3D	MAGMASoft	ProCAST
Suitability for filling simulation	Excellent	Moderate	Excellent
Discretization method	Finite-difference method (Multi-block control volume)	Finite-difference method (Voxel)	Finite-element method
Element Shape	Regular (structured) meshes: Rectangular elements 	Regular (structured) meshes: Rectangular elements 	Irregular (unstructured) meshes: Tetrahedral elements 
Free surface flow	VOF	VOF	VOF

FLOW-3D, MAGMASoft and ProCAST employ the VOF technique for simulating free surface flow. The VOF method although remains the most popular and widely used method for mould filling simulation. The reasons are its relative ease of implementation and its basis in volume fractions which lends itself well to incorporation of other physics.

V. Conclusion and Future Directions

FLOW-3D and MAGMASoft are finite-difference with control volume method (volume block-structured mesh generation), which built on structured grids use the sequential solution of balance equations, which results in large space in memory requirement. While ProCAST is a finite-element solver and uses volume tetrahedral meshes, which built on un-structured grids and usually exploits the simultaneous solution of all balance equations. It results in smaller space. It offers the simulation of fluid flow in the fully three-dimensional space and possibility to include model of the mould in the analysis.

The experimental results indicate that both ProCAST and FLOW-3D are suitable for simulating the filling step of jewelry investment casting. ProCAST allows user to play with most of the process including the run parameters, while FLOW-3D offers the ready-setting parameters. In ProCAST, boundaries could be assigned in forms of node, surface, interface and volume, while FLOW-3D allows assignment only on entire surface boundary face. However, more experiments in the computer-based simulation and the real casting are still required to ensure and confirm the studying interaction between filling behavior and process parameters.

This comprehensive approach extends the possibilities in exploring and understanding the complex interactions between process parameters or processing conditions, casting alloy, filling and metal flow, and solidifications. As a result, we spend lower production cost and time than conventional method. Opposite to the real casting process, the experimental configuration 'virtual casting' allows full control of the experimental conditions and the full scale of measurements of temperature and velocity. Collection of the quantitative transient data of the flow should permit to verify and validate the numerical models used for particular casting problems.

ACKNOWLEDGMENT

The authors sincerely express their grateful thanks to Dr. Pongsak Dulyapraphant, head of Casting Technology Program (CTP), National Metal and Material Center (MTEC), National Science and Technology Development Agency (NSTDA), Ministry of Science and Technology, Thailand, for kindly cooperating and providing the simulations in MAGMASoft. The authors also express their sincere appreciations and thanks to Mr. Dario Tiberto and Mr. Lorenzo Porta for their intensive works and very kind supports. Special thanks to Dr. Filip Kielar for proof reading of the original manuscript.

REFERENCES

[1] M. Actis Grande, L. Porta, and D. Tiberto, “Computer simulation of the investment casting process: widening of the filling step”, in *Santa Fe Symposium on Jewelry Manufacturing Technology*, 2007, pp. 1-16.

[2] J. Fischer-Büehner, "Advances in the prevention of investment casting defects assisted by computer simulation," in *Santa Fe Symposium on Jewelry Manufacturing Technology*, 2007, pp. 193-216.

[3] C. L. Atwood, “Chapter 10 Metal Casting Applications: Overview of the Investment Casting Process”, in *Rapid Prototyping in Europe and Japan, Volume I. Analytical Chapters*, WTEC Hyper-Librarian, 1997.

[4] X. J. Zhang, K. K. Tong, R. Chan, and M. Tan, “Gold Jewellery Casting: Technology Design and Defects Elimination,” *Journal of Materials Processing Technology,* vol. 48, pp. 603-609, 1995.

[5] Wikipedia web site, “Computational fluid dynamics”. Available *http://en.wikipedia.org/wiki/Computational_fluid_dynamics* Retrieved 27 October 2008

[6] H. Karema, and S. Lo, “Efficiency of interphase coupling algorithms in fluidized bed conditions,” *Computers & Fluids,* vol. 28, pp. 323-360. 1999.

[7] L. Westerlund, J. Dahl, and R. Hermansson, “Heat and mass transfer simulations of the absorption process in a packed bed absorber,” *Applied Thermal Engineering*, vol. 18, pp. 1295-1308, 1998.

[8] P. Cleary, J. Ha, V. Alguine, and T. Nguyen, “Flow modelling in casting processes”, *Applied Mathematical Modelling,* vol. 26, pp. 171-190, 2002.

[9] S. Wannarumon, “Comparisons of Simulation Software Programs used for Jewellery Investment Casting,” M.Eng. Thesis, Dept. of Material Sciences and Chemical Engineering, Politecnico di Torino, Alessandria, Italy, 2008.

[10] J. C. Wright, “Computer simulation and jewelry production”, in *Santa Fe Symposium on Jewelry Manufacturing Technology*, 2005, pp. 521-535.

[11] J. Fischer-Büehner, "Computer simulation of investment casting," in *Santa Fe Symposium on Jewelry Manufacturing Technology*, 2006, pp. 193-216.

[12] M. Actis Grande, A. Zambruno, M. Rosso, S. Bezzone, and A. Incognito, “Computer simulation of the investment casting process: experimental validation”, in *TCN CAE Conference*, Lecce, Italy, 2005, pp. 63-73.

Somlak Wannarumon was born in Lampang, Thailand, on the 19th of January 1973. She graduated in Bachelor of industrial engineering (B.Eng.) with the Second Honors at Chiang Mai University, Chiang Mai, Thailand since the year 1994. During her study, she earned Best Student Award in the year 1992 and 1993. She earned M.Eng. in Manufacturing System Engineering from Asian Institute of Technology, Pathumthani, Thailand in the year 2000 with her thesis title ‘Product design and manufacturing using rapid prototyping for the jewelry industry**’.** She received her PhD in design and manufacturing engineering from the Asian Institute of Technology in 2007, with her dissertation title ‘Aesthetic Evolutionary Approach for Jewelry Design based on IFS Fractals’.

During the year 1994-1996, Somlak had been worked in Thai Paper Industry Co., Ltd., Siam Cement Group, Bangkok, Thailand, in a position of industrial engineering, who worked on marketing and production coordinator, production planning, database system development and ISO 9002. She turned herself to the academic direction since the year 1997. She is currently a lecturer-in-charge at Department of Industrial Engineering Naresuan University, Faculty of Engineering, Phisanulok, Thailand. She worked additionally as an industrial consultant in the projects under Thailand Department of Industrial Promotion, Ministry of Industry during the year 2000-2003. She earned the best research award from Naresuan Univeristy in the year 2007. She teaches in several courses: product design and development, research methodology, value engineering, project feasibility study, engineering statistics, engineering economics and quality control. She earns the researcher fellowship to join the INTOGOLD research project at Politectnico di Torino Sede di Alessandria in the year 2009. Her scientific research areas cover Computer Aided Design and Manufacturing, and Rapid Prototyping (CAD/CAM/RP); Artificial Intelligence in Product Design: Expert System, Evolutionary Algorithm, etc.; Computational Aesthetics: Aesthetic Measure, Algorithmic Aesthetics; Value Engineering in Product Design; Integration of Automatic Design and Manufacturing. She applies her researches to jewelry design and manufacturing applications, also extents to other applications such as numerical simulation of casting process, biomedical engineering, etc.

Dr. Wannarumon is an active member of Thailand Council of Engineer in the position ‘Associate Industrial Engineer’ since June 1994. She is a peer-reviewer of The World Scientific and Engineering Academy and Society (WSEAS) in the field of product design, artificial intelligence in design, and computing aesthetics. She is also a member of the scientific and technical committee and editorial reviewer board on natural and applied science of World Academy of Science, Engineering and Technology (WASET).

Marco A. Grande was born in Cuneo (Italy), on the 19th of December 1973, in 1999 he got his M.Sc in materials engineering at Politecnico di Torino (Italy), after having developed a thesis at the University of Nottingham (UK) on the reactive sintering of TiC reinforced stainless steels. In 2002 he joined the PhD course in Metallurgy at Politecnico di Torino and in 2005 he got the degree, discussing a thesis entitled: “Process innovation and product improvement in the Duplex Stainless Steels forming via Powder Metallurgy”.

Marco is currently an Assistant Professor in Metallurgy; he teaches three courses at Politecnico di Torino – Sede di Alessandria – CESAL related to the Materials Science and Metallurgy; his scientific work is mainly focused on the metallurgical aspects related to sintered materials and jewelry. He published more than 60 papers, mainly focused on the mechanical properties of sintered steels, in particular stainless steels and on the wear phenomena. He is active in the precious metals sector, with several studies on the process simulation. In the last decade he participated to various EC and National projects, being either coordinator or technical/local supervisor, attracting also private industrial funding both from Italy and EU. He is also editor of the Proceedings of TOOL06 Int. Conference, 2 – 5 May 2006, Torino, Italy, ISBN:88-8202-019-3

Dr. Actis Grande is an active member of the Centre of Study of Non Ferrous Metals as well as the Secretary of the Centre of Study of Powder Metallurgy, of the Italian Association of Metallurgy (AIM). He is also a member of the Research, Education and Training (RET) group of the European Powder Metallurgy Association (EPMA). In 2007 he was awarded of the 'Outstanding Technical Presentation' at the Santa Fe Symposium on Jewelry, Albuquerque (USA).