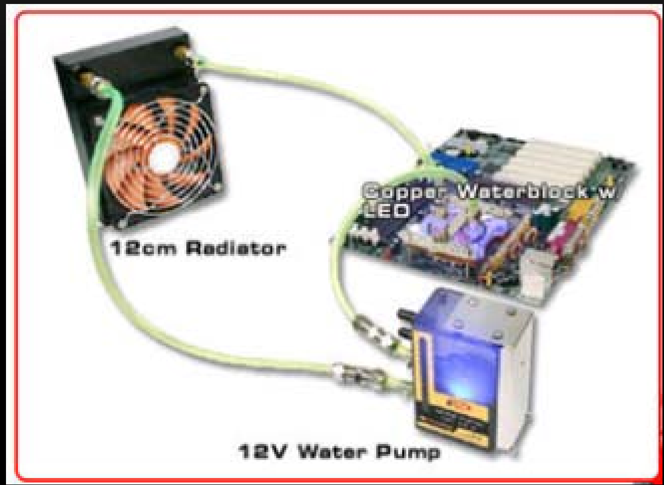
COMSOL Multiphysics ---
Innovative Designs and Engineering
COMSOL --- 創意產品設計和工程

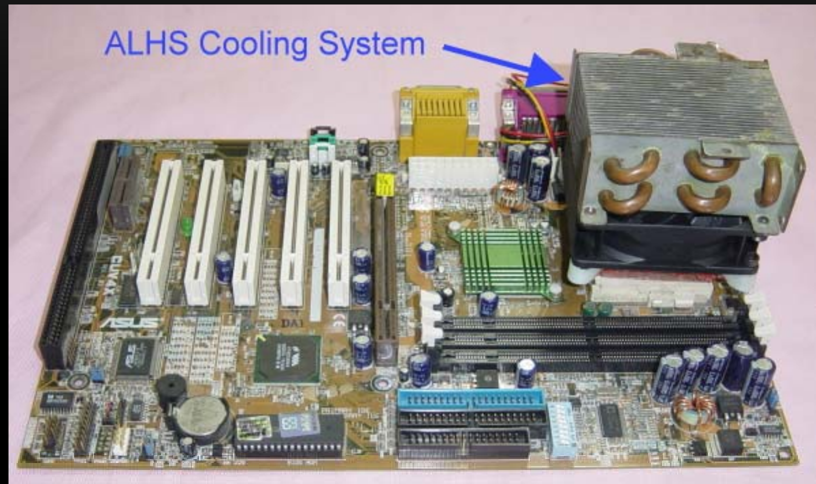
Songhao Wang
Kun Shan University
09/24/2012

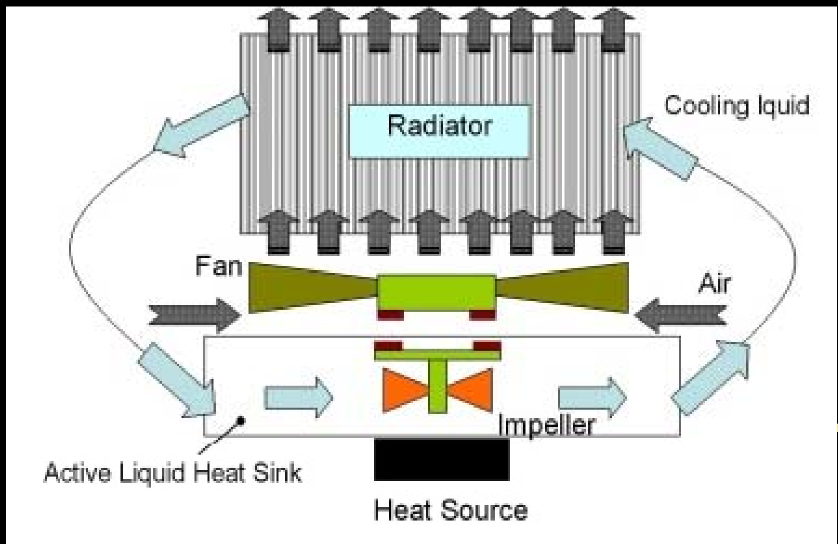
Innovative Researches Projects that needed COMSOL

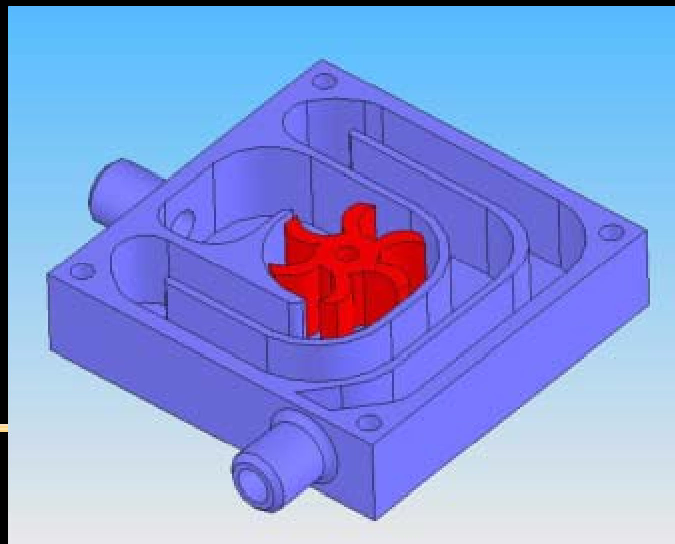
1) Simulation of the Fluid Dynamics in Active Liquid Heat Sink for CPU Cooling System；
   作動式隧道型晶片散熱器
2）Study of Impeller Design for Pipe Flow Generator with CFD；
   管流發電機葉片設計
3）A Study on Investment Casting Directly with Plastic Rapid Prototype Patterns；
   塑膠快速原型件直接用於脫蠟鑄造製程
4）Phase Changing Material Used with RP Technology in Quick Wax Molding for Investment Casting；
   相變化材料結合快速原型技術進行快速蠟模製造
5）A Study of Rooftop Insulation Material for Energy Efficiency；
   屋頂隔熱材料層的優化
6) The Design of Solar Chimney that Combined with Solar Panel；
   結合太陽能板的太陽能煙囪設計

1) Simulation of the Fluid Dynamics in Active Liquid Heat Sink for CPU Cooling System；作動式隧道型晶片散熱器

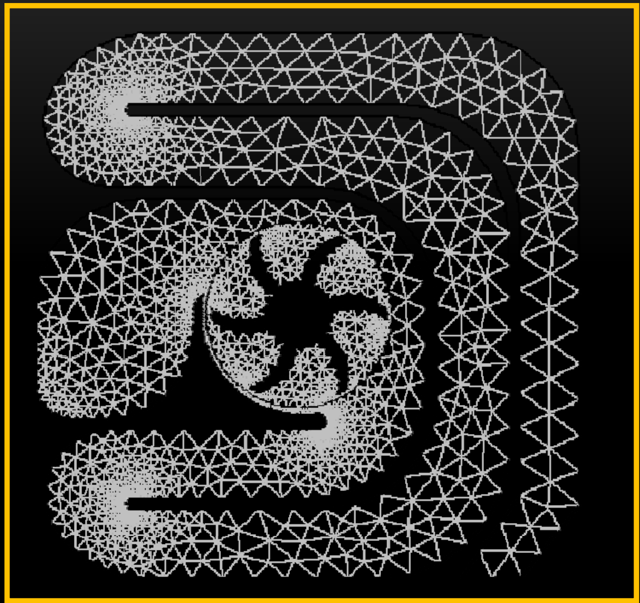


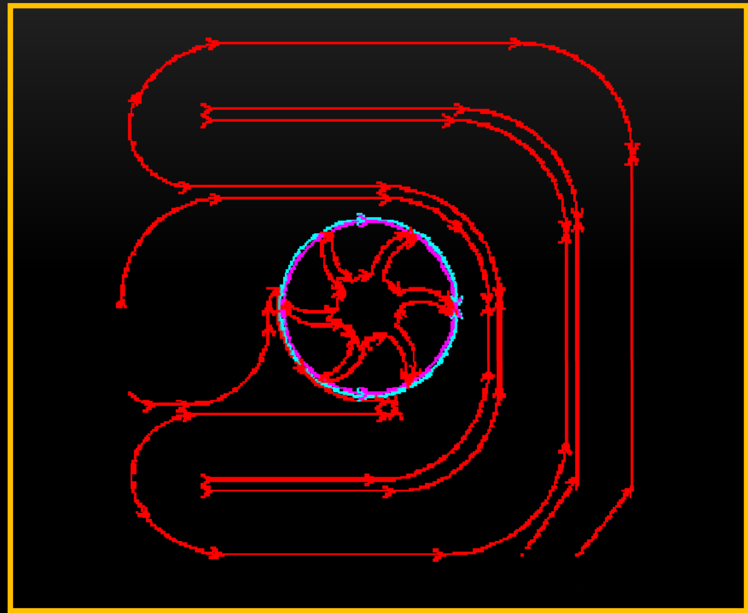


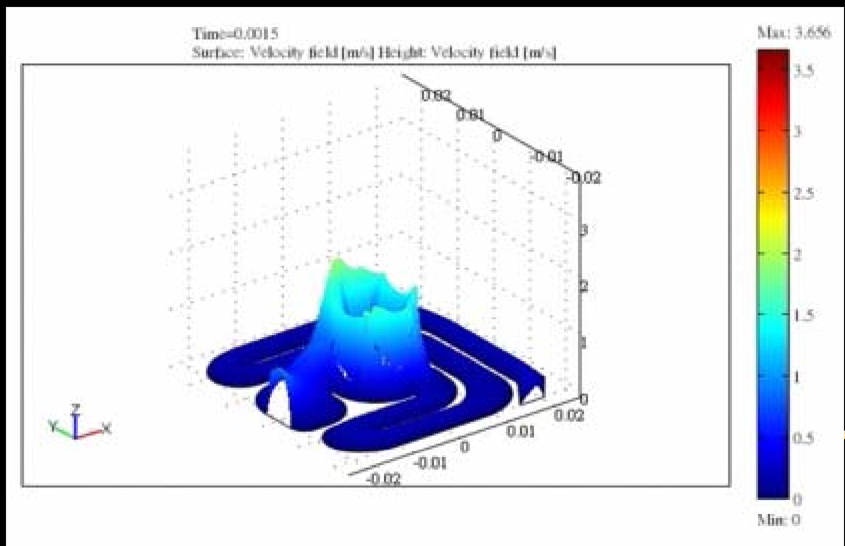


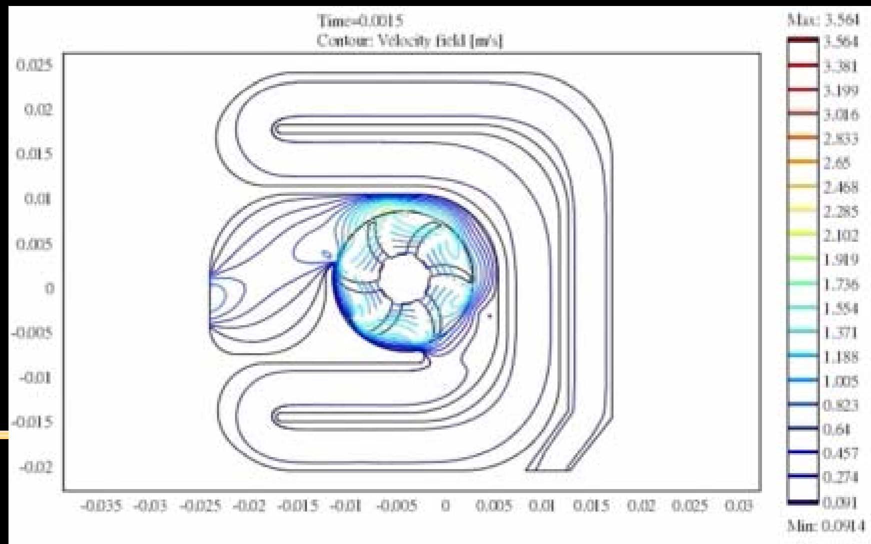


1) Simulation of the Fluid Dynamics in Active Liquid Heat Sink for CPU Cooling System；
作動式隧道型晶片散熱器

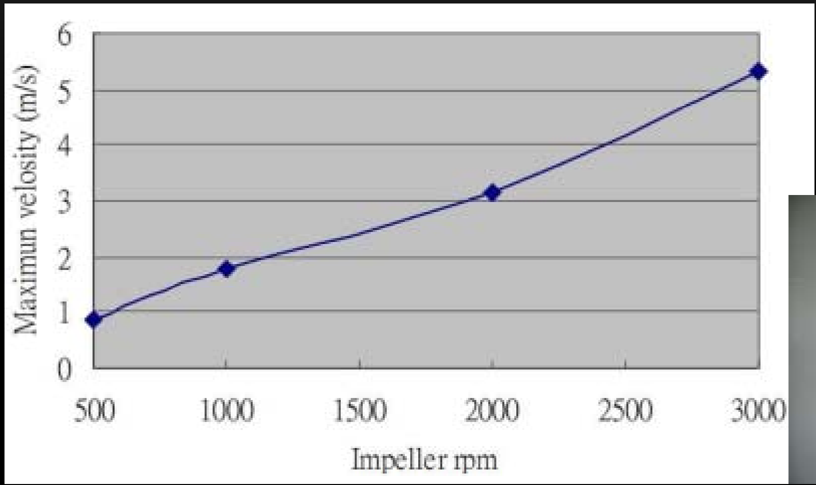


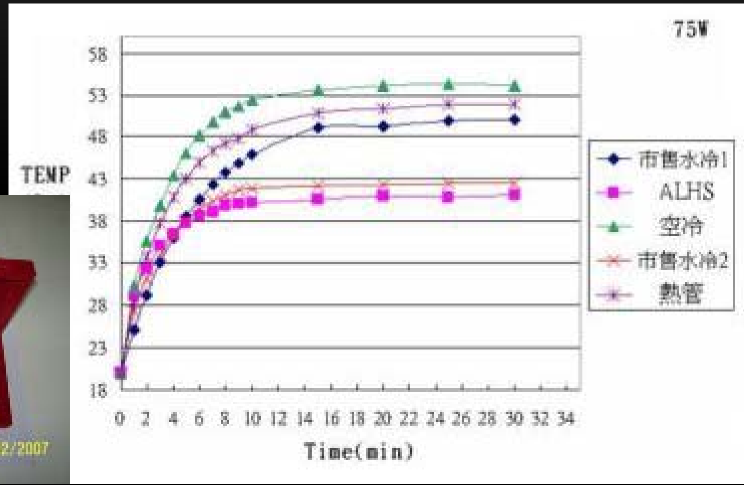




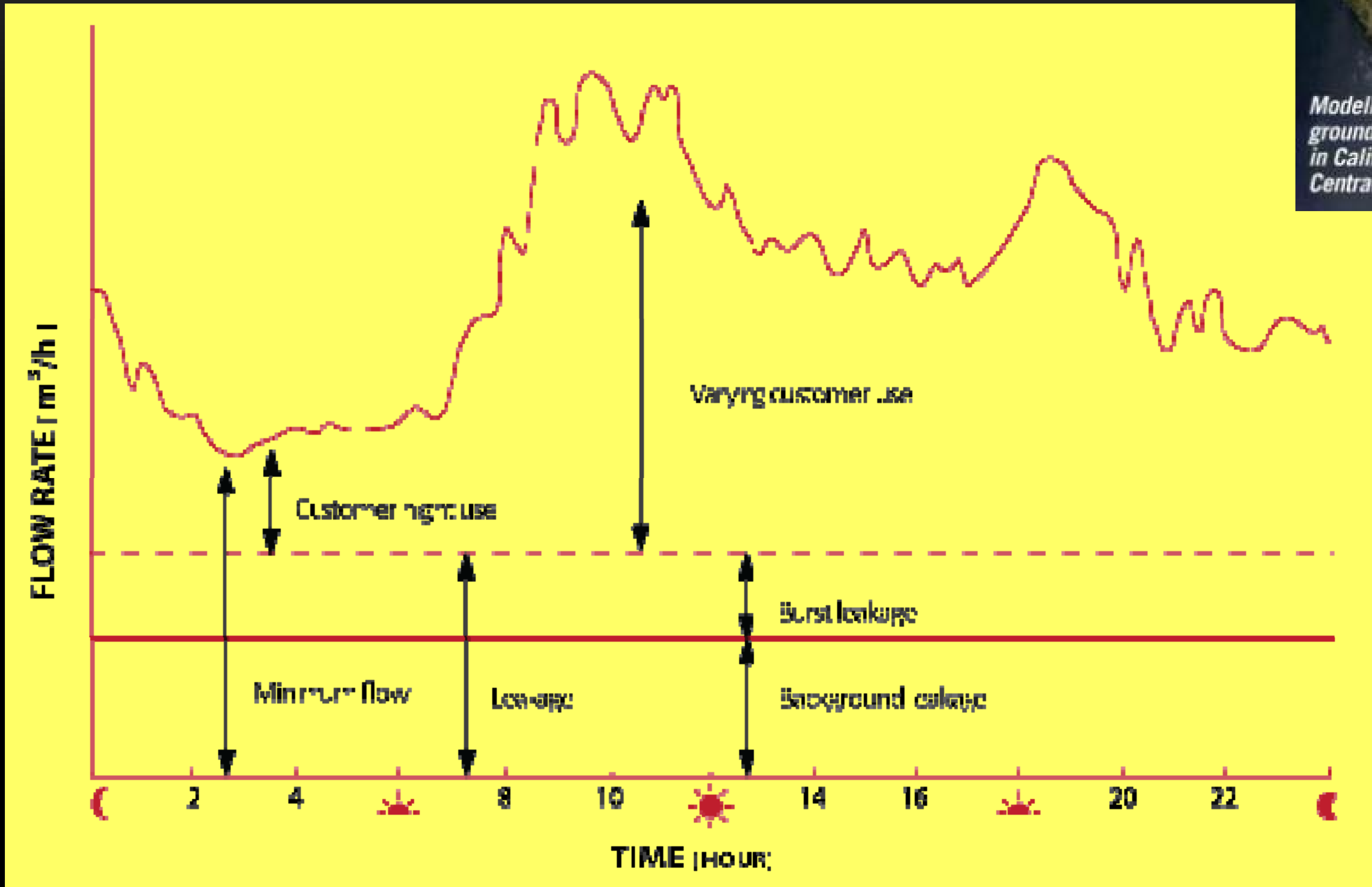


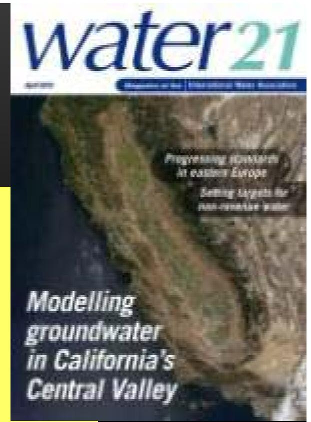
1) Simulation of the Fluid Dynamics in Active Liquid Heat Sink for CPU Cooling System；作動式隧道型晶片散熱器



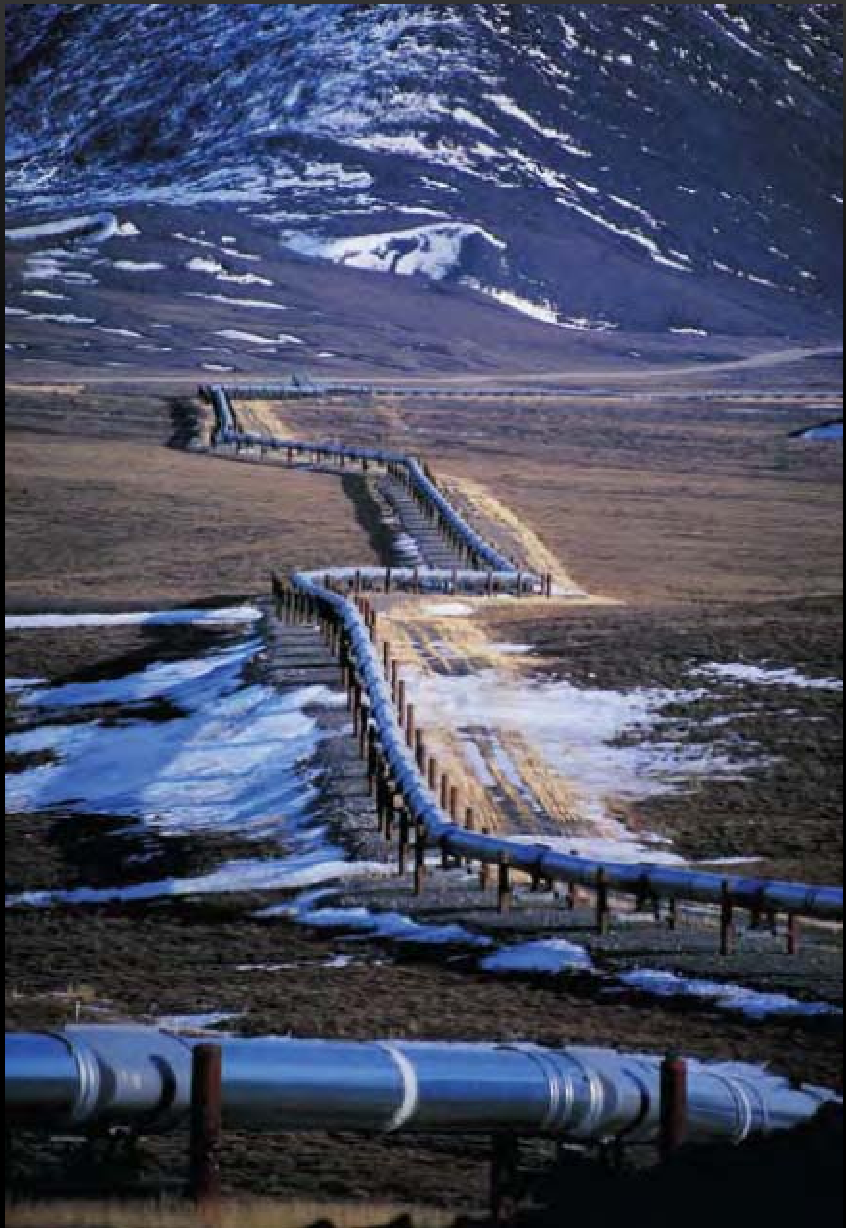


2）Study of Impeller Design for Pipe Flow Generator with CFD；
管流發電機葉片設計



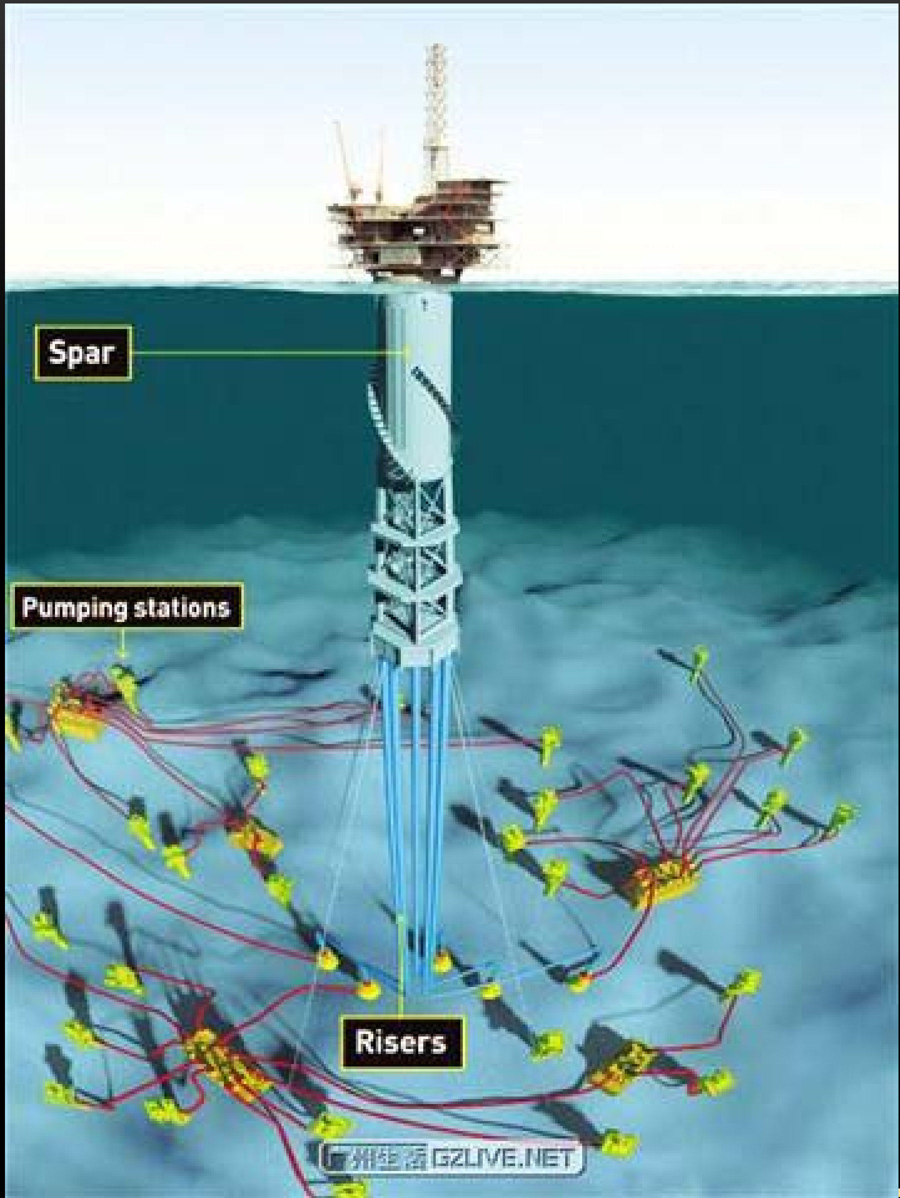


In most of the countries water leakage are over 20%，
in some developing countries it could be as high as 50% !

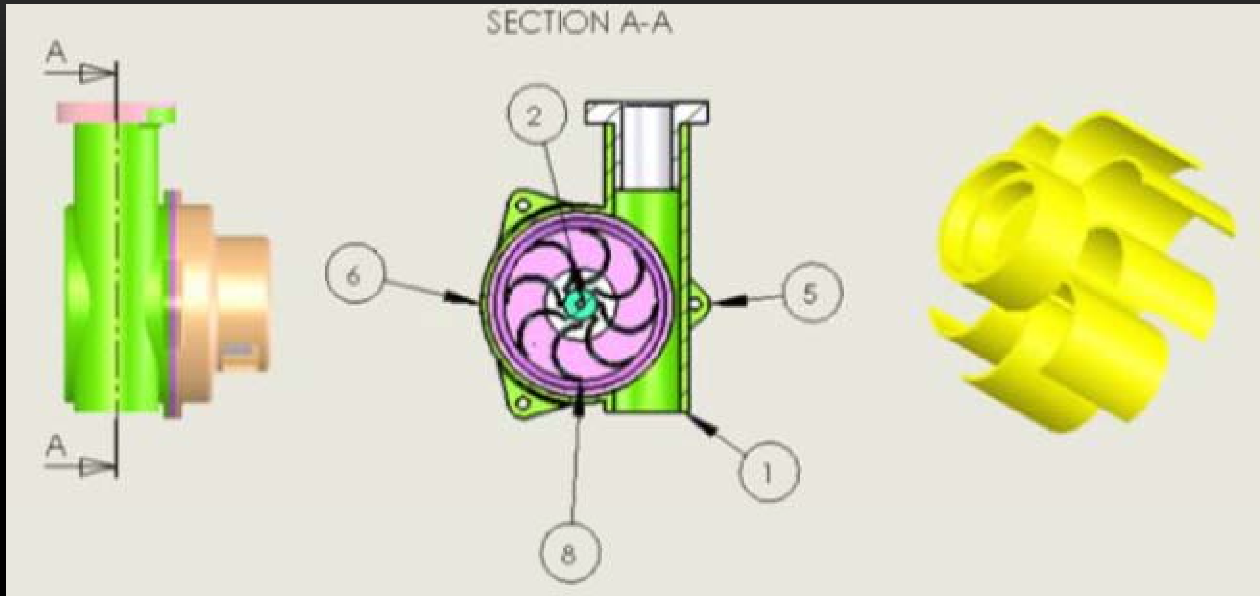


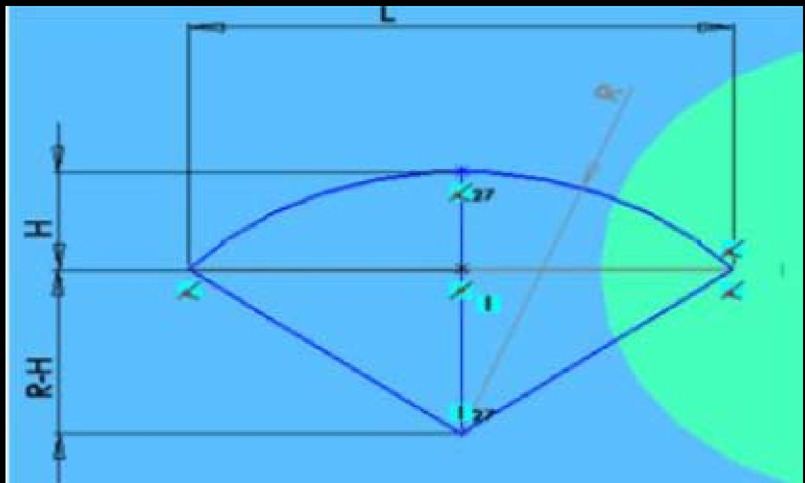
In natural habitats, desert and rural areas

荒山野外以及沙漠地區的水管



Pipelines in Deep Sea Drilling





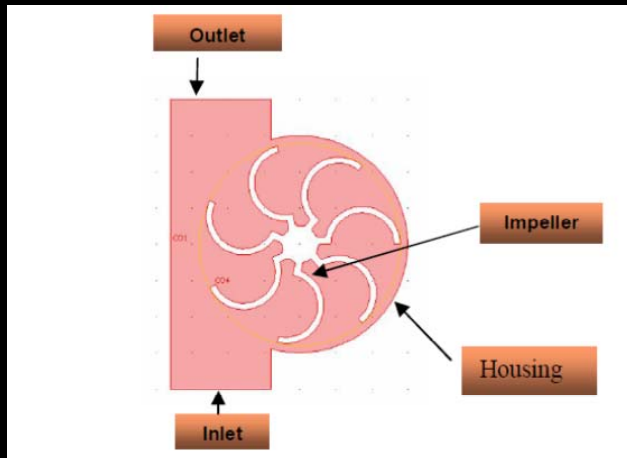
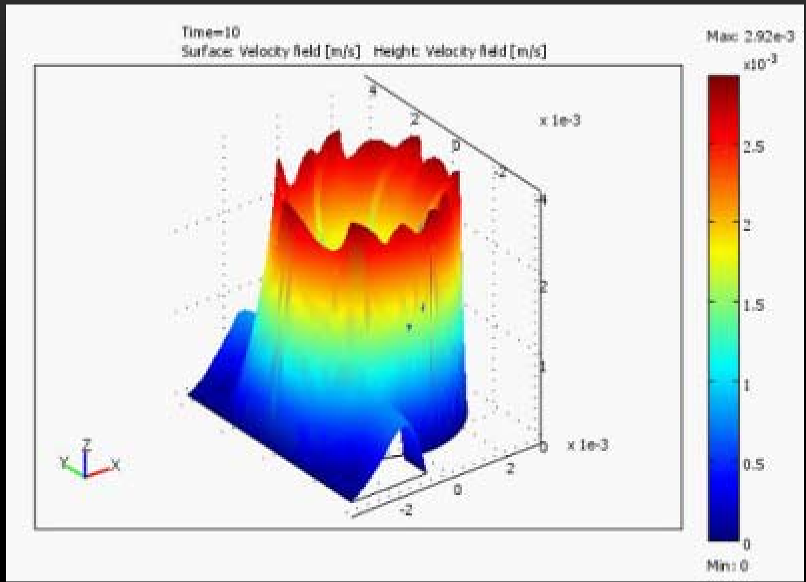
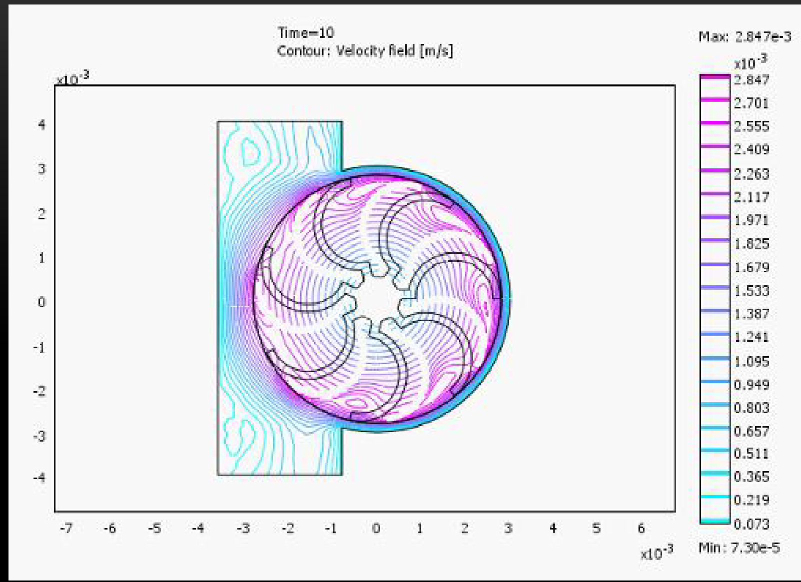


Fig. 3 Geometry model in COMSOL interface





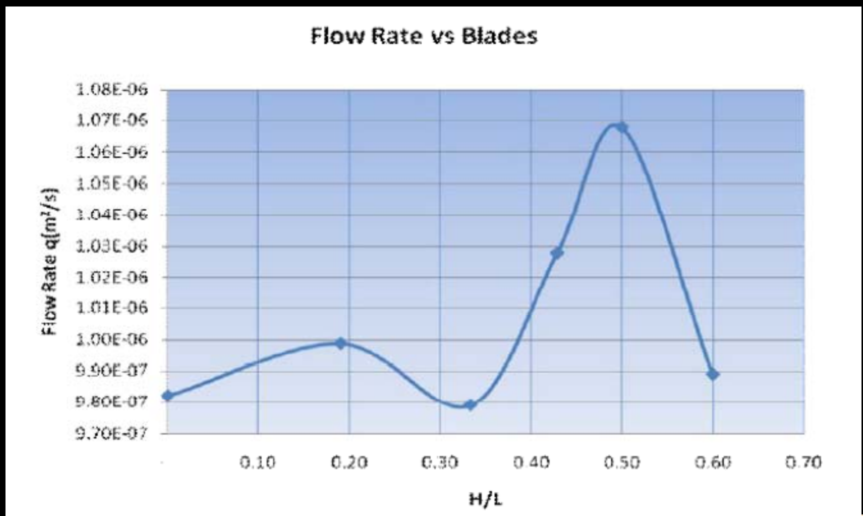


Fig. 6 Flow Rate vs. blade curvature H/L

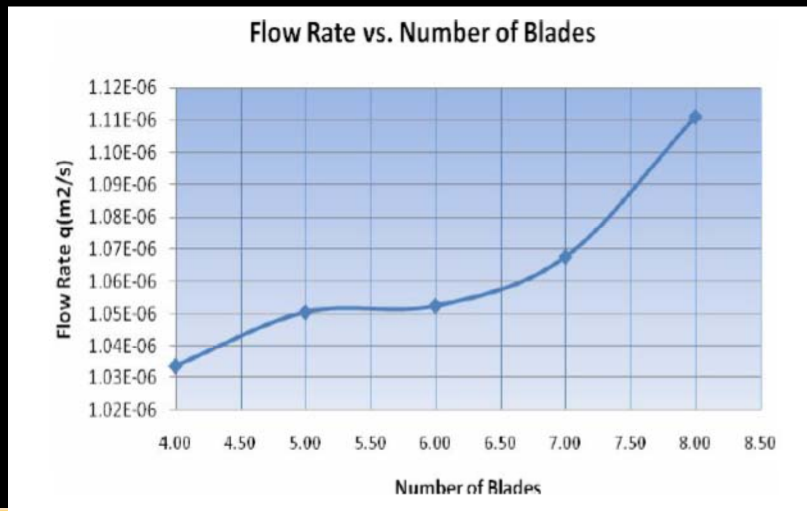
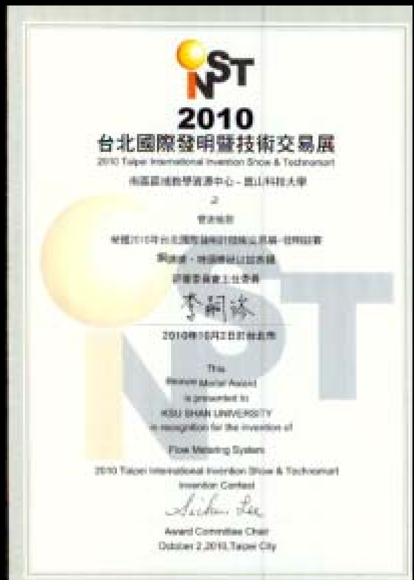


Fig. 7 Flow rate vs. number of blades

The SPFM System is operating without external power
不用電池運行

Mini-wheel W-116
110V Wired Electricity

SPPFM
No Battery Needed



Self-Powered, Multi-Chanel Flow Monitoring System
with Wireless Communication

3）A Study on Investment Casting Directly with Plastic Rapid Prototype Patterns；
塑膠快速原型件直接用於脫蠟鑄造製程

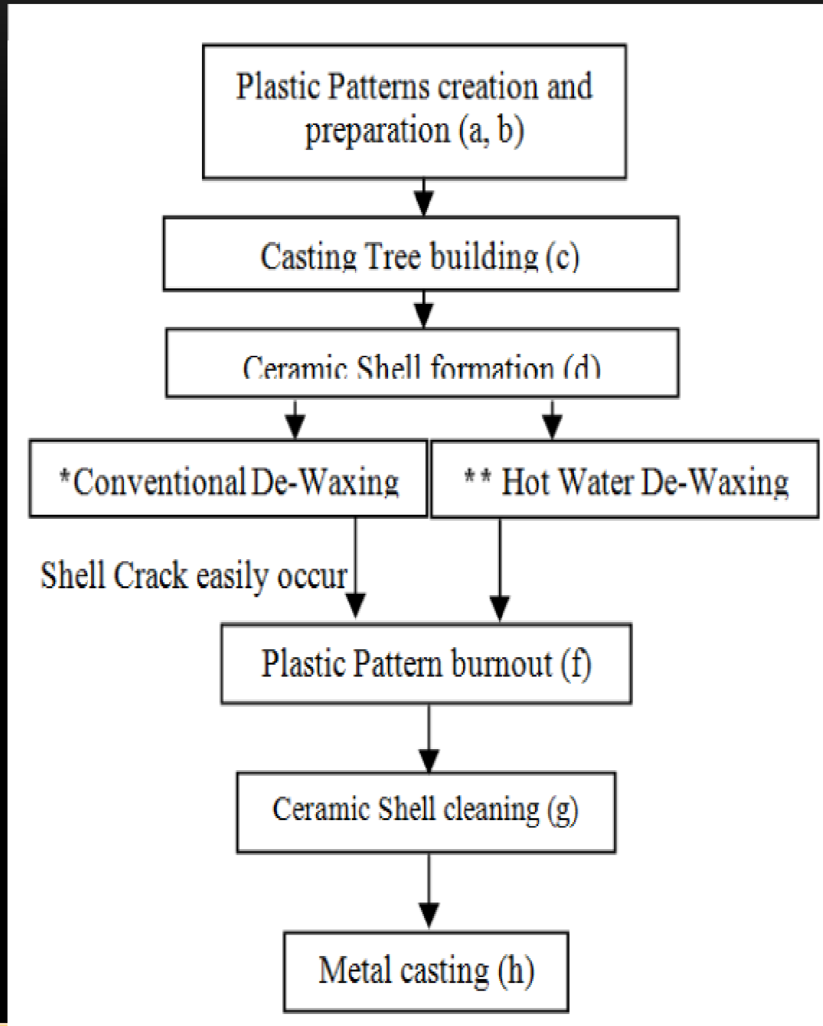


Fig. 2 Block diagram of key steps of the process.

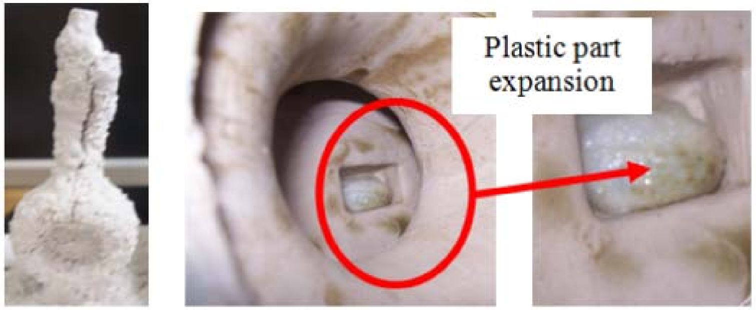


Fig. 8 Plastic material flow observed after regular De-Wax process.

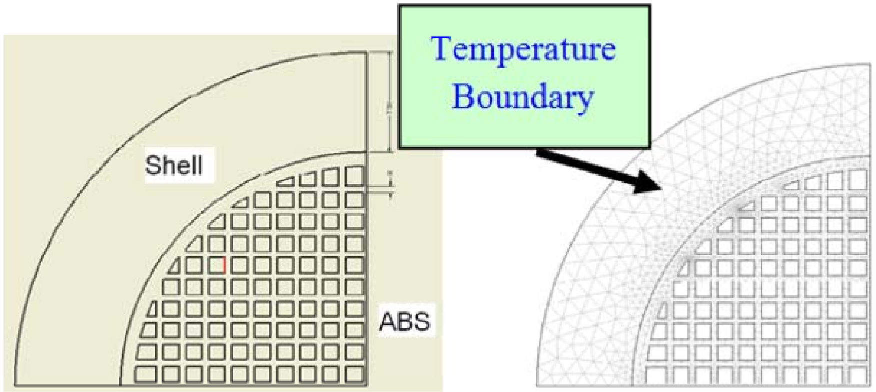


Fig. 13 Physical model and mesh situation from COMSOL Multi-physics[R].

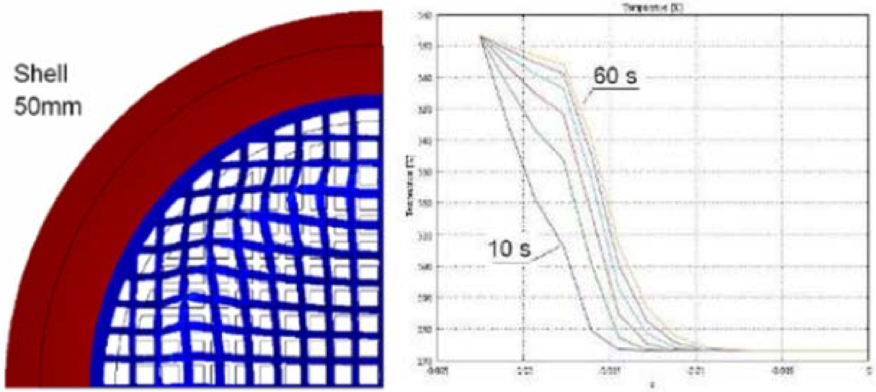
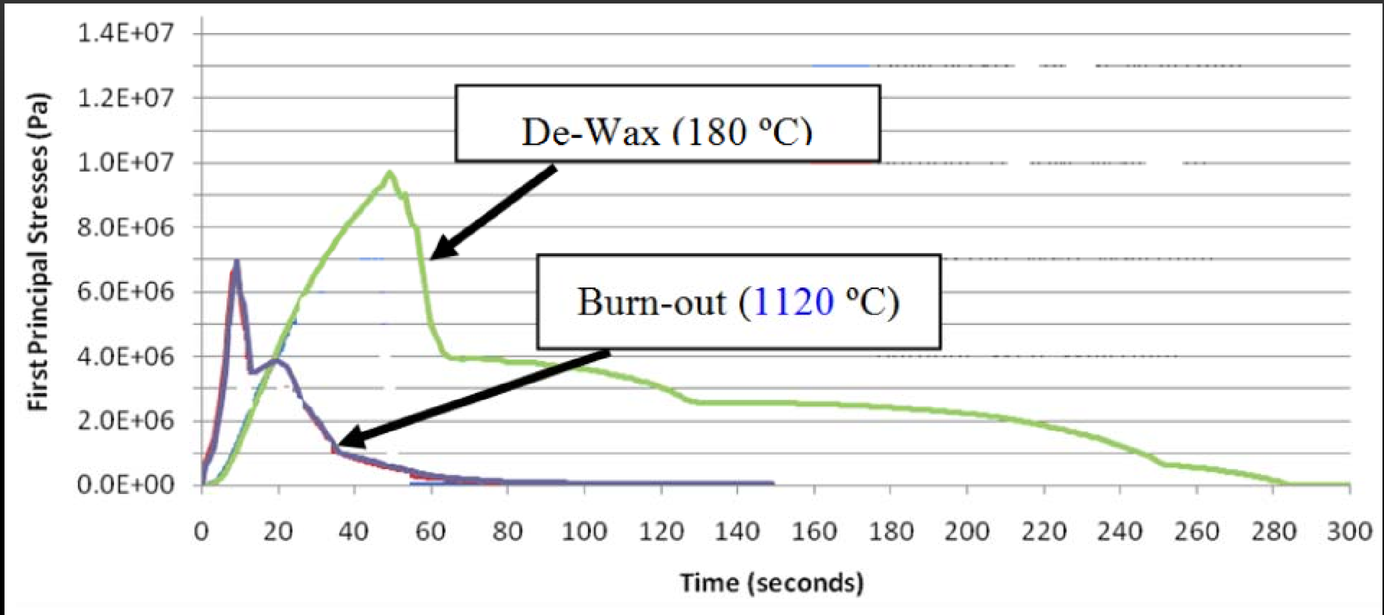
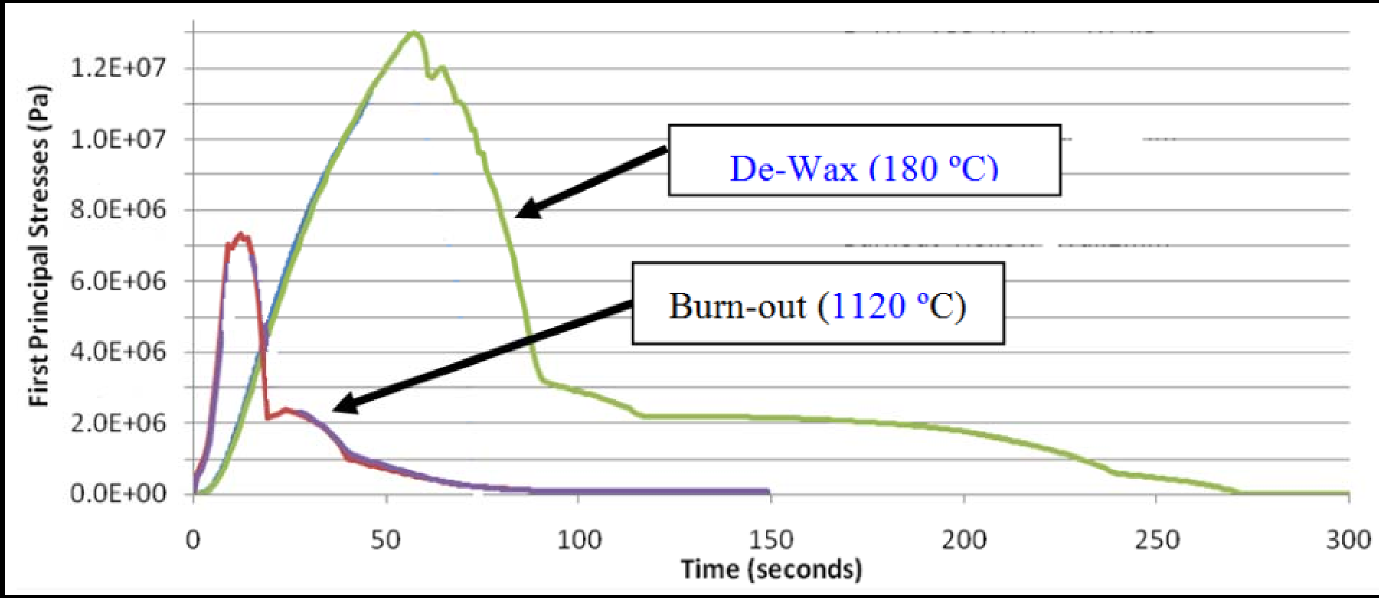


Fig. 14 Temperature propagation towards inner structure



Shell stresses during de-waxing and Burnout (1 mm Wall).



Shell stresses during de-waxing and Burnout (2 mm Wall).

Materials and Manufacturing Processes, 25: 1482–1488, 2010

ISSN: 1042-6914 print/1532-2475 online
DOI: 10.1080/10426914.2010.529585

Taylor & Francis

A Study of Investment Casting with Plastic Patterns

S. Wang[1], A. G. Miranda[1], and C. Shih[2]

[1]*Department of Mechanical Engineering, Kun Shan University, Yong Kang, Taiwan*
[2]*Kang Tion Metal Industrial Co. Ltd., Tainan, Taiwan*

This article presents a study of plastic pattern used in investment casting as expendable material. Numerical analyses of transient heat transfer coupled with structural mechanics were conducted in order to study the thermal stresses inside a ceramic shell under both dewaxing (180°C) and burnout temperatures (1120°C). Moreover, the sensitivity of thermal stresses to the nonlinear thermal and mechanical properties of plastic patterns are reviewed and discussed. It was found that the thermal stress is most sensitive to the glass transition temperature, followed by the coefficient of thermal expansion of plastic patterns. Not only are the results valuable for plastic rapid prototyping (RP) patterns, but they will serve as guidelines for introducing plastic patterns from injection molding to investment casting, due to the wide range of plastics available. Therefore, these results will make the investment casting process more versatile and successful, providing high-temperature metal and metal alloy parts with more precision, more repeatability, lower production costs, and labor in high volume production for small or mini metal parts.

Keywords Investment casting; Numerical analysis; Plastics; Thermal stress; Transient.

Introduction

With the development of technologies, rapid prototyping (RP) and rapid manufacturing (RM) have become more popular due to a more competitive market. RP focuses on small quantities and complex geometries, and its application on investment casting gives designers the freedom to rapidly modify and redesign a product without a significant increase of the total development time and cost. RM focuses on fast production, reducing lead time and labor [1].

Traditional investment casting processes use wax as the expendable material; therefore, it is sometimes called *lost wax casting*. After the wax patterns are made and attached to a wax tree, they are dipped in slurry (composed of refractory powders and a binder) to create layers that, after air drying, will act as a ceramic shell. A dewaxing process will take place to remove the wax by placing the dried ceramic shell inside an oven at a temperature of about 180°C. The wax will melt and flow outside the ceramic shell. This removed wax can be reused after the dewaxing process, lowering material costs. Then the hollow ceramic shell will be exposed to higher temperatures, typically around 1120°C, for two purposes: further hardening to withstand the stresses and vacuum creation when the molten metal is poured into the empty ceramic shell.

Patterns made from wax have properties that limit their application in precision casting, especially for pieces with thin geometries that readily break or deform when handled or dipped in the refractory slurry. Moreover, because molds have to be built to make the wax patterns, making "lost wax casting" not economically sound when only a small number of pieces are required. Building a large number of very small wax patterns, however, leads to more intensive labor and more cost.

In the above situations, plastic may be a good alternative for the expendable patterns. If the production volume is low or only samples of metal pieces are needed, RP technology can be employed. For large number of very small patterns, another technology can be applied to investment casting; that is, plastic injection molding. Plastic injection molding can solve the problem of high production limits of RP and still produce small parts with thin walls that traditional investment casting cannot build easily and efficiently.

For RP processes, stereolithography (SLA) machines cure a photosensitive liquid (resin or epoxy) and fused deposition modeling (FDM) machines extrude molten plastic to build an expendable part. Some modifications of the traditional process and some changes in the Computer Aided Design (CAD) design must be made in order to adapt them to investment casting.

For example, in the case of epoxy patterns from SLA, dewaxing temperatures make the epoxy expand to the point where it cracks the ceramic shell. In order to solve problem, studies suggested that it is necessary to c inner webs (also called *lattice structure*) that not only material but make their application more successful This practice was studied with a steady-state finite ele analysis (FEA) [3]. Studies and advances made the l structures evolve from simple rectangular to triang hexagonal, and finally to octagonal. The octagonal l structure reduces stresses on the ceramic shell conside (62% compared to hexagonal), improves drainage ab and reduces internal mass by 42% (compared to hexago among other improvements [4].

Many FDM processes use plastics such as acrylon butadiene styrene (ABS) and polycarbonate (PC). application of these plastic patterns in investment ca has proven to be efficient and adequate. How advantages of ABS over other RP plastic patterns inc

Received July 11, 2010; Accepted September 28, 2010
Address correspondence to S. Wang, Department of Mechanical Engineering, Kun Shan University, Yong Kang 710, Taiwan; E-mail: songhaow@hotmail.com

MAMP Journal

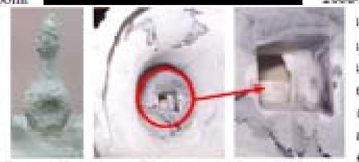


Fig. 11 Very clean ABS burn-out under 1120°C without shell crack.

Fig. 12 Successful quick-cast metal pieces with thin walls

November 2010, Volume 4, No. 11 (Serial No. 36)
Journal of Materials Science and Engineering, ISSN 1934-8959, USA

A Study on Investment Casting Directly with Plastic Rapid Prototype Patterns

Songhao Wang[1], Chinyang Shih[2] and Xinxin He[2]
1. Mechanical Engineering Department, Kun Shan University, Tainan 710, Taiwan
2. Kang Tion Metal Industrial Co. LTD, Tainan, Taiwan

Received: April 02, 2010 / Accepted: April 17, 2010 / Published: November 25, 2010

Abstract: This paper presents studies for Plastic RP pattern directly used in investment casting. Ceramic mold shell preparation procedures including CAD pattern designing, RP pattern formation, pattern surface finish and sealing, dewaxing and burnout are discussed. Geometrical effects such as bulk solid and thin wall are studied. For the process to be successful the preparation should start as early as CAD design stage. For bulk solid geometries, "Shell" function in CAD and "Sparse-web" options are proved very effective and should be applied in combination. Hot-Water De-Wax before burnout proved to be very effective, experimentally and theoretically.

Key words: Quick casting, rapid prototype (RP), plastics, ABS

1. Introduction

Rapid prototyping (RP) techniques applied in investment casting could reduce dramatically the lead-time and cost. It also gives the companies the freedom to issue new products rapidly without significant increase total development time and cost. The ideal RP pattern for investment casting is no doubt wax, such as Thermojet MJM wax and FDM ICW06 wax. However based on Wohlers' 2008-RP-Report in Fig. 1, more than 70% of RP units ice parts that are made of thermo plastic or io-set [1], simply because at present the RP units used by companies are used for multi-functions ly for demonstration and sampling, but also for d run pieces.

e major advantages of RP plastic/resin parts for investment casting are [2]:

(1) It eliminates the need for tooling. Injection molds for wax patterns range from $3,000 to $30,000, and

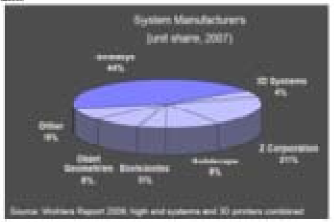


Fig. 1 Wohlers' report on Rapid Prototyping 2008 [1].

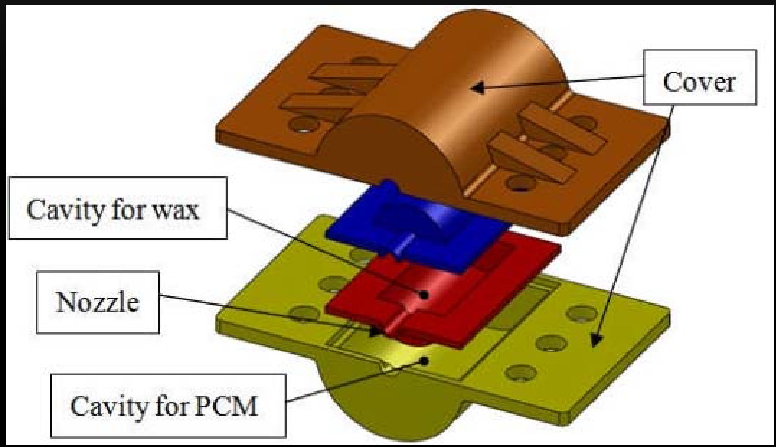
building the tools can take four to six weeks. With this technology, the tooling cost is eliminated and the lead-time for a cast part is slashed to just 10 days on average. This yields a savings of $30,000 and two to four weeks for a typical project, which makes investment casting viable for prototype quantities. The time and cost savings are true no matter how complex the part's design.

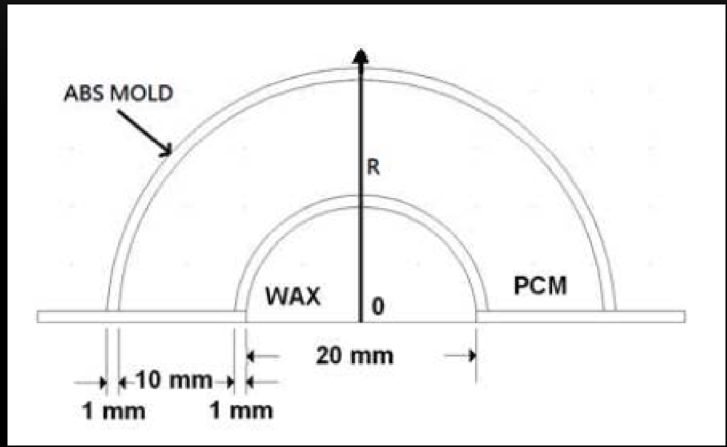
rresponding author: Songhao Wang (1951-), male, as professor, research field: rapid prototyping, reverse neering, creative product design. E-mail: aow@hotmail.com.

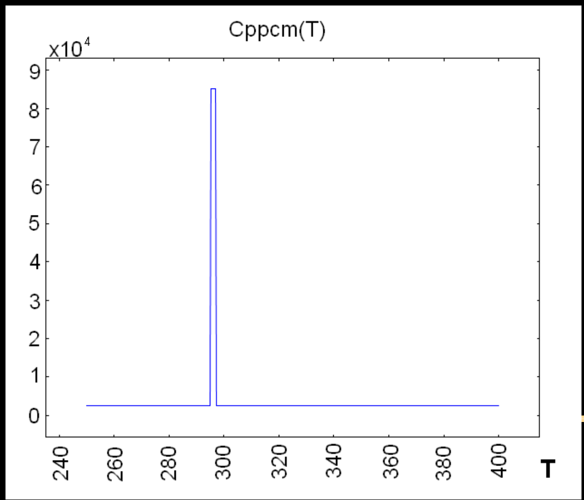
JMSE

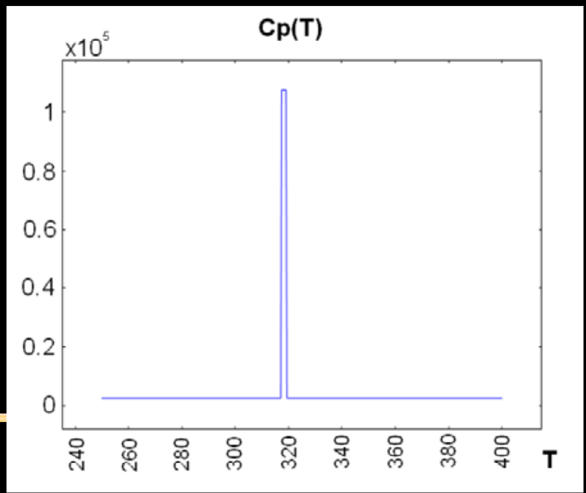
4）Phase Changing Material Used with RP Technology in Quick Wax Molding for Investment Casting；

相變化材料結合快速原型技術進行快速蠟模製造









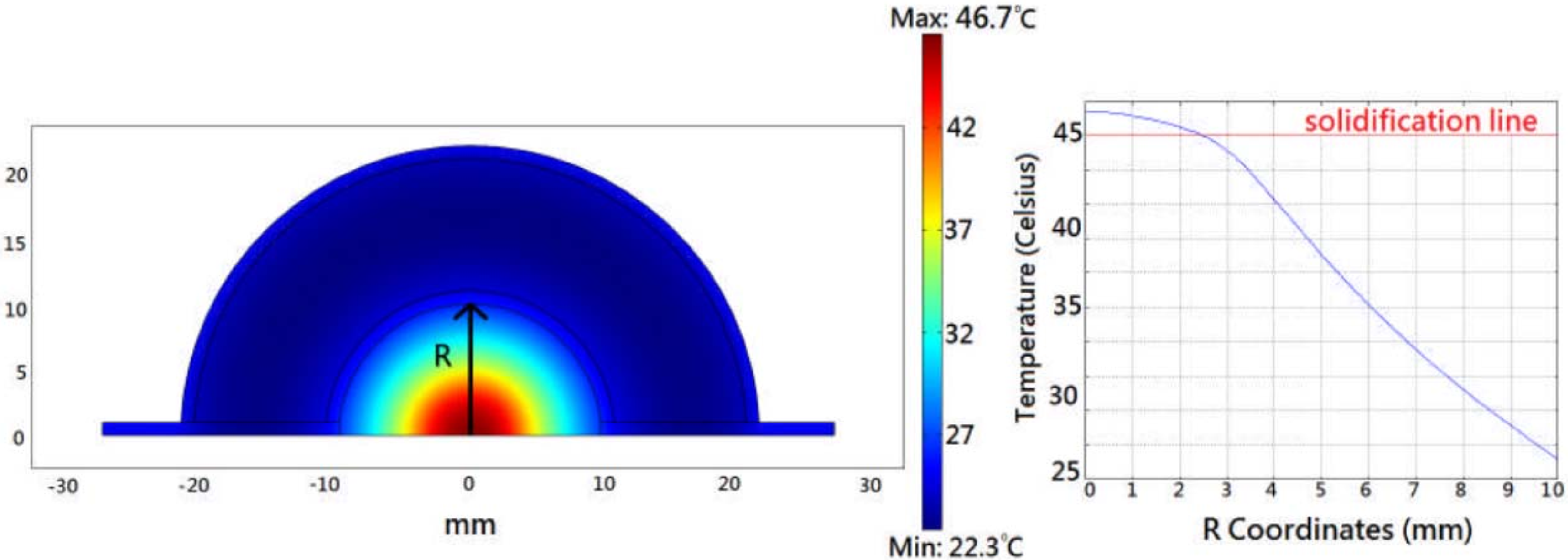


Fig. 8: 2D simulation after 20 minutes (1226 seconds) of cooling.

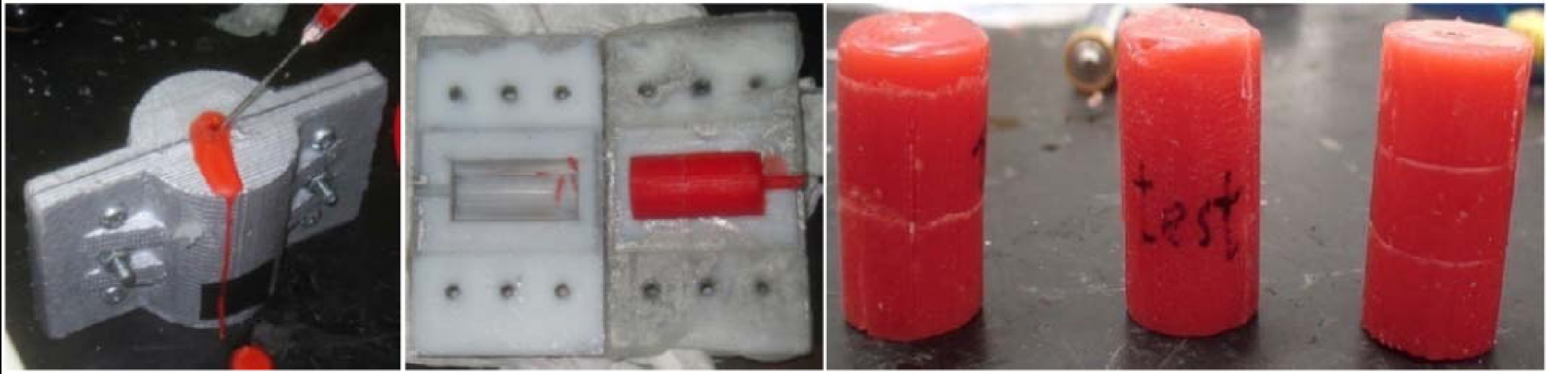


Fig. 7: Wax injection (left), mold open (center), completed pattern (right).

DOI 10.1007/s00170-011-3784-6

ORIGINAL ARTICLE

Rapid prototype mold for wax patterns with the help of phase change materials

Songhao Wang · Joseph Dié Hassan Millogo

Received: 6 August 2011 / Accepted: 14 November 2011 / Published online: 9 December 2011

Abstract This paper presents a new process to produce wax patterns using a rapid prototyping made mold and a phase changing material (PCM). A numerical simulation of the system was performed to fully understand the melting and heat absorption behavior of PCM and injected wax. To do so, the specific heat of PCM and wax was modified to account for the increased amount of energy in the form of latent heat of fusion over its melting temperature range. Then, a carefully prepared experiment successfully confirmed the validity of the work. Comparable to traditional wax pattern process, this new method opens a new window to obtain wax patterns with less time and more geometry complexities while providing good accuracy. Moreover, optimization by practicing different thermal conductivity of metallic–powder–PCM mixture revealed a possibility of further shortening wax solidification time, making this process competitive with the traditional process.

Keywords Heat transfer · Investment casting · Mold · PCM · Rapid prototype · Wax pattern

1 Introduction

Investment casting is one of the traditional processes for manufacturing metal parts. It can produce complicated shapes that would be difficult or impossible with techniques such as die casting, yet it requires less surface finishing and only minor machining [1]. Wax patterns are usually necessary for the process.

With the development of technologies, rapid prototyping (RP) and rapid manufacturing quickly gained popularity due to their flexibility and their competitiveness on the market, whose application in investment casting gives designers the freedom to rapidly modify and redesign a product without significant increase over the previous development time and cost. Some researches were done to compare the efficacy of two powder-based 3D printing RP technologies for rapid casting of light alloys [2]. Metal parts were also made by investment casting with RP ice patterns [3]. Moreover, rapid casting of free-form surface parts was realized via replacing wax patterns by stereolithography patterns for single and small batch production [4]. Although some studies were done to use plastic RP patterns directly in investment casting as expendable material with good results, a plastic pattern can only produce one corresponding metal part [5]. Therefore, alternative process is needed to produce more than one part with a plastic rapid prototyping mold.

The employment of thermal energy storage can change the world of energy today as it refers to a number of technologies that store energy in a thermal reservoir for later use. The storage capacity and the possibility of using latent heat energy storage systems (LHESS) are due to the fact that some materials, such as phase changing material or PCM, have a large heat of fusion that can be used to store thermal energy. The modes of heat transfer encountered in the melting and solidification of PCM are mainly conduction, convection, and close contact melting. As demonstrated in the following section of this paper, the convection mode can be neglected while the close contact melting plays an important part only during start-up period [6, 7].

In this paper, a proposed new method was implemented by the RP technology combined with a PCM to produce wax patterns. A numerical simulation has been conducted to study the transient heat transfer process that occurs after injecting paraffin wax in an acrylonitrile

S. Wang (✉) · J. D. H. Millogo
Department of Mechanical Engineering, Kun Shan University, Tainan, Taiwan
e-mail: songhaow@hotmail.com

J. D. H. Millogo
e-mail: Coolio_51@yahoo.fr

IJAMT

Computer-Aided Design and Applications

Phase Changing Material Used with RP Technology in Quick Wax Molding for Investment Casting

[1]Songhao Wang and [2]Joseph D. Millogo

[1]Department of Mechanical Engineering, Kun Shan University, Taiwan, Songhaow@hotmail.com
[2]Department of Mechanical Engineering, Kun Shan University, Taiwan, coolio_51@yahoo.fr

ABSTRACT

This paper presents a study of replacing, in the domain of wax injection molding process, the traditional metallic mold with a mold made of a RP plastic material combined with a PCM material. The process being studied here uses melted paraffin wax as the injection material. Numerical simulation of transient heat transfer was conducted with COMSOL multi-physics software. The behavior of the melting and heat absorption of PCM was simulated by modifying the specific heat of the material to account for the increased amount of energy in the form of latent heat of fusion over its melting temperature range. ABS plastic mold was made through FDM Rapid Prototyping process and a carefully prepared experiment was successfully conducted. To confirm the validity of the numerical simulation, the data acquired during the experiment was compared with the numerical results and the outcome was satisfactory.

Keywords: wax mold, investment casting, PCM, heat transfer, rapid prototyping.
DOI: 10.3722/cadaps.2012.409-418

1 INTRODUCTION

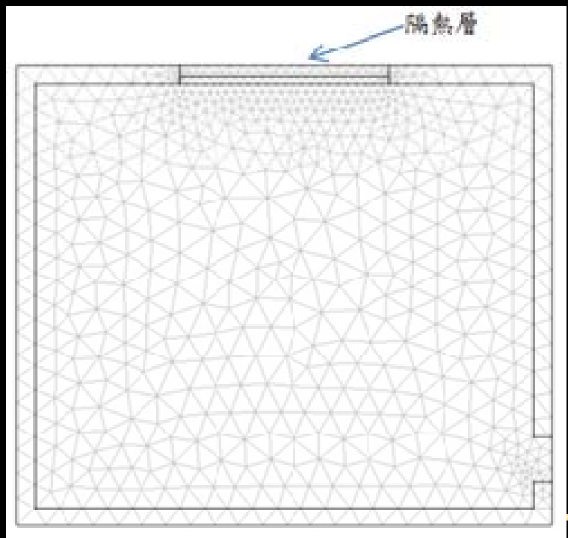
All around the world, engineers strive hard in order to improve existing tools, produce newer, more creative and most importantly more useful tools, in order to make daily lives easier. Investment casting is one of the processes that were invented for that objective. It is an industrial process based on one of the oldest known metal-forming techniques. It can produce complicated shapes that would be difficult or impossible with die casting yet it requires little surface finishing and only minor machining [7]. Traditional investment casting process uses wax as the expendable material therefore it is sometimes called "lost wax casting". After the wax patterns are made and attached to a wax tree, they are dipped in ceramic slurry (composed by refractory powder and binder) to create layers that, after air drying, will act as a ceramic shell. A de-waxing process will take place to remove the wax by placing the dried ceramic shell inside an oven at the temperature about 180˚C. The wax will melt and flow outside the ceramic shell. This removed wax can be reused after the de-waxing process lowering material costs. Then the hollow ceramic shell will be exposed to higher temperatures, typically around 1120˚C, for two purposes: further hardening to withstand the stresses and create a vacuum when the molten metal is poured in to form metal parts.

With the development of technologies, Rapid Prototyping (RP) and Rapid Manufacturing (RM) quickly gained popularity due to their flexibility and their competitiveness on the market. RP focuses

Computer-Aided Design & Applications, 9(3), 2012, 409-418

CAD & A

5）A Study of Rooftop Insulation Material for Energy Efficiency；
屋頂隔熱材料層的優化



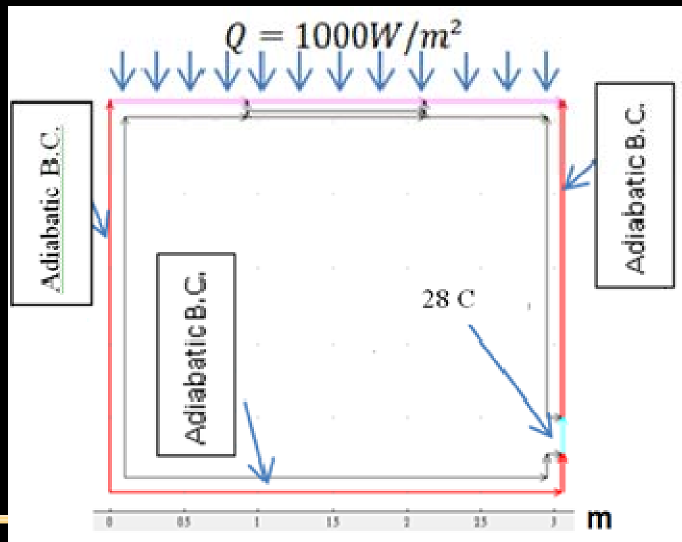
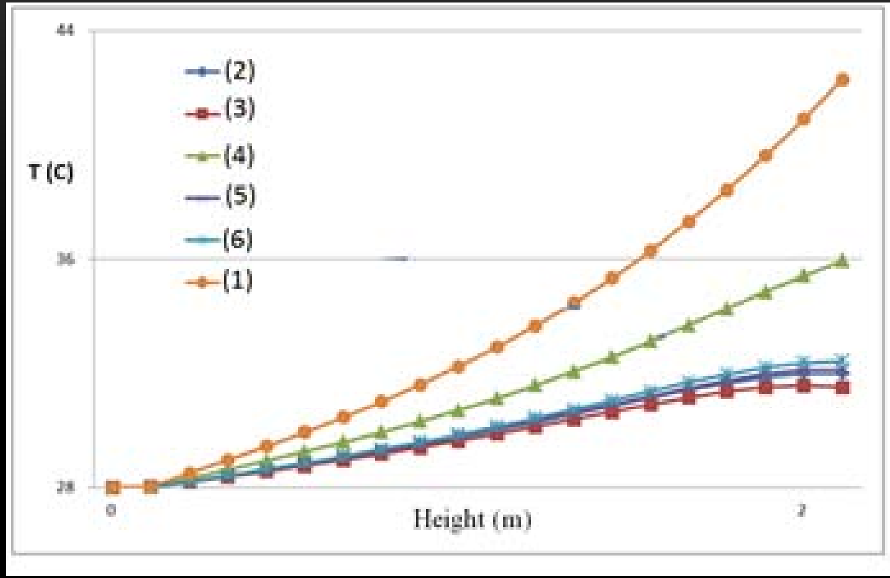
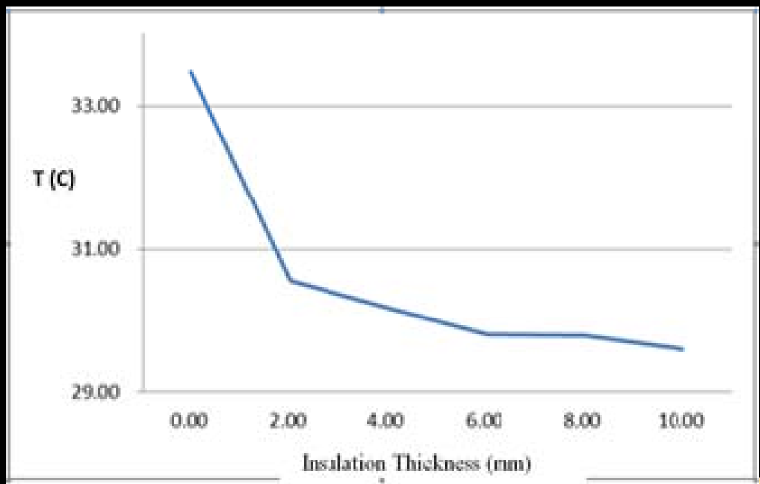
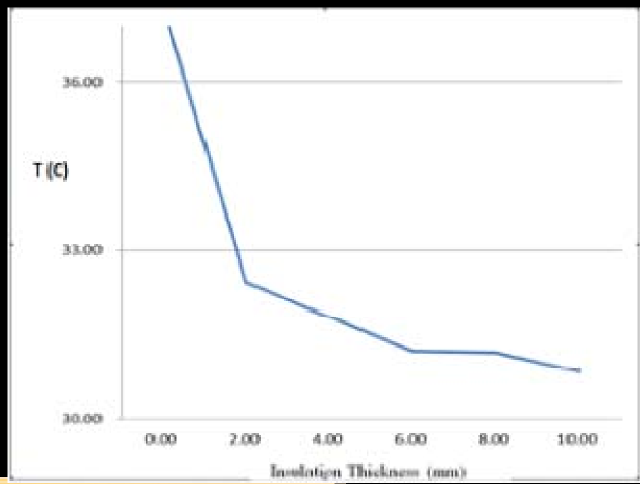


Table 1 Thermal conductivity K for different Materials [8]

	Insulation Brick Type	Thermal Conductivity K （W/m.K）
(1)	Concrete	1.3
(2)	Recycled Wood-Concrete Insulation Brick	0.157
(3)	Recycled Buber Insulation Brick	Rubber layer：0.036 Styrofoam Layer：0.039
(4)	Recycled Insulation Brick （B3 & C50）	0.653
(5)	Five-Leg Insulation Brick	0.163
(6)	Styrofoam Insulation Brick	Concrete Layer：2.2 Styrofoam Layer：0.0489

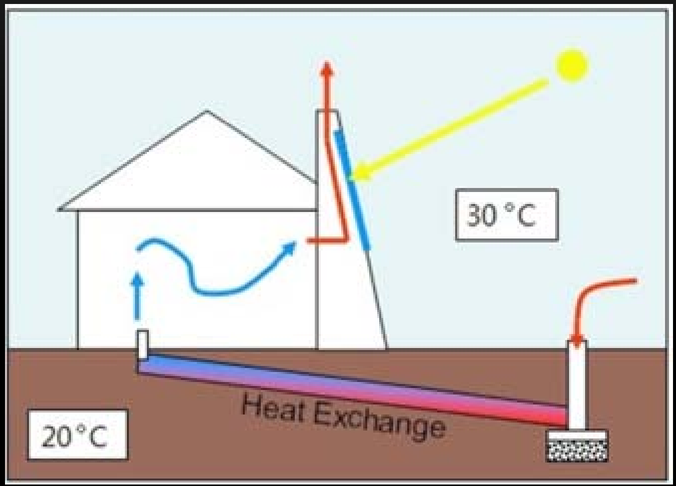


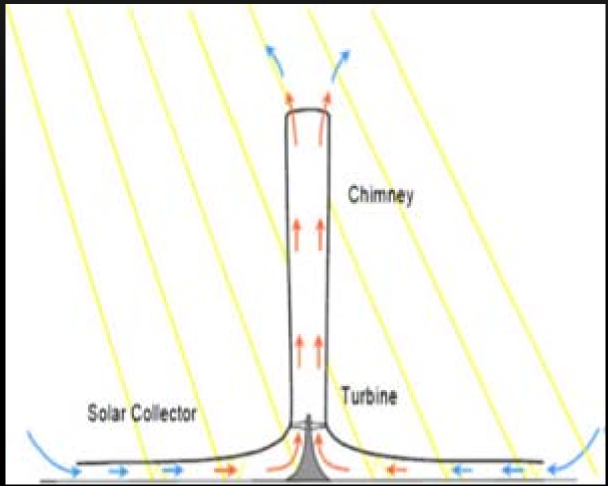


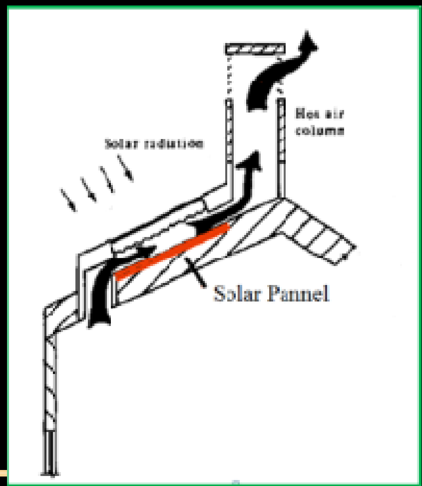


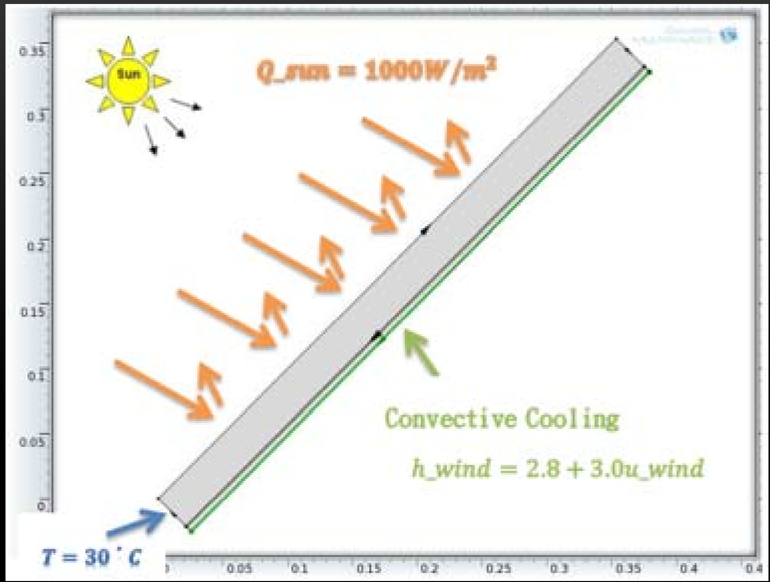
6）The Design of Solar Chimney that Combined with Solar Panel；

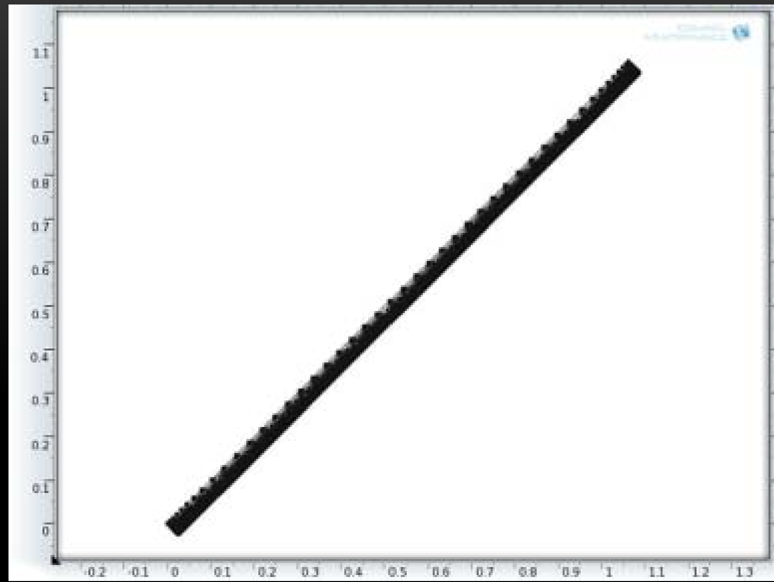
結合太陽能板的太陽能煙囪設計

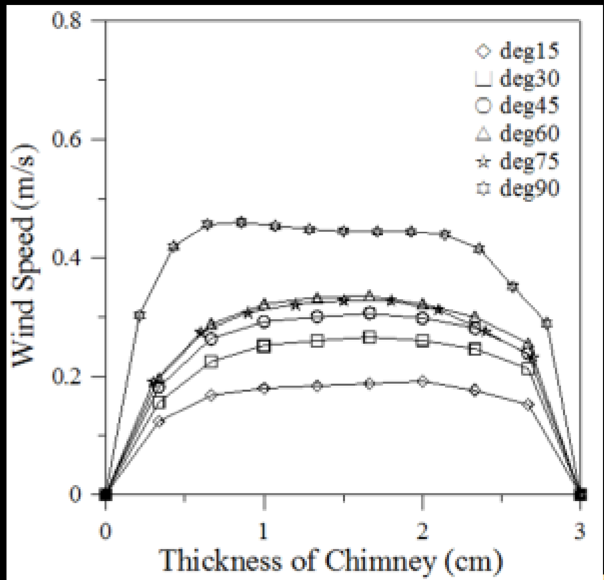


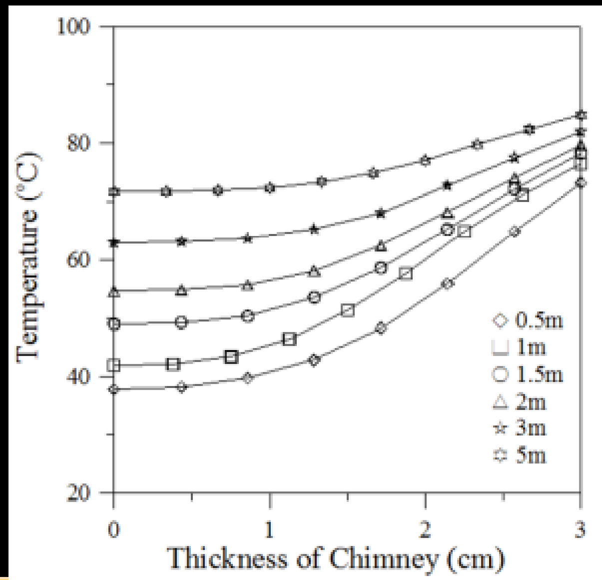





Sun
Q_sun = 1000W/m²
Convective Cooling
h_wind = 2.8 + 3.0u_wind
T = 30 °C




Wind Speed (m/s)
Thickness of Chimney (cm)
deg15
deg30
deg45
deg60
deg75
deg90


Temperature (°C)
Thickness of Chimney (cm)
0.5m
1m
1.5m
2m
3m
5m

Thanks