COMSOL Multiphysics --- Innovative Designs and Engineering

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
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. 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-Channel Flow Monitoring System with Wireless Communication
A Study on Investment Casting Directly with Plastic Rapid Prototype Patterns.

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®.

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).
A Study on Investment Casting with Plastic Patterns

S. Wang, A. G. Miranda, and C. Shi

1Department of Mechanical Engineering, Kan Yan University, Hong Kong T3, Taiwan, E-mail: shaomingw@ncku.edu.tw
2Kang-Tai Metal Industrial Co. Ltd., Tainan, Taiwan

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 to 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 (comprising 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 ceramic shell inside an oven at a temperature of about 1800°C. The wax will melt and flow out of the ceramic shell. This removed wax can be reused as the dewaxing process, saving material costs. After the wax is removed, the 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.

Compared to wax, plastic has properties that limit their application in precision casting, especially for pieces with thin walls or high cavity area. However, the latest generation of RP machines are capable of printing 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 costs.

In the above situations, plastic may be a good alternative to the expendable patterns. If the production volume is low or only samples of metal pieces are needed, RP technology can be applied for investment casting. Additionally, it is possible for plastic injection molding. Plastic injection molding can solve the problem of high production volumes of RP fabrication and still produce small parts with thin walls that traditional investment casting cannot build quickly and efficiently.

For RP processes, stereolithography (SLA) machines cure a photopolymerizable liquid (resin or epoxy) and laser projection printing (FDM) machines extrude molten plastic to build an expensurable mold. Some modifications of the traditional process and some new methods and designs (CAD) design must be made to adapt them to investment casting. For example, in the case of spray patterns from SLA, removing the support makes the part very expensive due to the material cost of RP parts. For this, the support must be built and the RP process must be expensive (Fig. 1).

The RP method for building investment casting is not as expensive as the traditional method. It also gives the operator the freedom to build very complex and large parts with higher similarity and lower cost compared to traditional methods. RP technology offers great potential in various applications such as prototyping, education, and research. RP technology has been widely used in the automotive industry and various other fields such as aerospace, medicine, and dental implants.
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. 7: Wax injection (left), mold open (center), completed pattern (right).

Fig. 8: 2D simulation after 20 minutes (1226 seconds) of cooling.
Rapid prototype mold for wax patterns with the help of phase change materials

Songkao Wang · Joseph D. Millingo

Received: 6 August 2011 / Accepted: 14 November 2011 / Published online: 9 December 2011
© Springer-Verlag London Limited 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 modeled 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. Compatible 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-golden-PCM mixture revealed a possibility of further shortening was 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. 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 researchers were done to compute the efficacy of rapid prototyping for investment casting of low alloy [2]. Metal parts were also made by investment casting with RP wax 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 (LHES) 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 phase change. A detailed discussion is given in the following section of this paper, the convection mode can be neglected while the 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 acrylic resin.

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

Songkao Wang and Joseph D. Millingo

Department of Mechanical Engineering, Kansai University, Osaka, osamu_wang@kansai-u.ac.jp

ABSTRACT

This paper presents a study of replacing 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 melt 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 RP Molding 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: 10.3727/cadaps.2012.409-418
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]

<table>
<thead>
<tr>
<th>Insulation Brick Type</th>
<th>Thermal Conductivity K (W/m.K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>1.3</td>
</tr>
<tr>
<td>Recycled Wood-Concrete Insulation Brick</td>
<td>0.157</td>
</tr>
<tr>
<td>Recycled Buber Insulation Brick</td>
<td></td>
</tr>
<tr>
<td>Recycled Insulation Brick (N3 &amp; C50)</td>
<td>0.653</td>
</tr>
<tr>
<td>Five-Leg Insulation Brick</td>
<td>0.163</td>
</tr>
<tr>
<td>Styrofoam Insulation Brick</td>
<td></td>
</tr>
</tbody>
</table>

- Rubber layer: 0.036
- Styrofoam Layer: 0.039
- 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
Thanks