UNIVERSITI PUTRA MALAYSIA

COMPUTER AIDED DESIGN AND ANALYSIS IN DIE/MOULD OF CASTING PROCESS

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By

MD. SHAMSUL ABEDIN

Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering, University Putra Malaysia

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UPM

DEDICATED TO

My parents

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ABBREVIATIONS AND NOMENCLATURES

CAD : Computer Aided Design

CAM : Computer Aided Manufacturing

CAA : Computer Aided Analysis

CAE : Computer Aided Engineering

FEA : Finite Element Analysis

VDU : Visual Display Unit

DBMS : Database Management System

IGES : Initial Graphics Exchange Specification

DXF : Drawing Interexchange File

AME : Advanced Modelling Extension

A : Cross-sectional area (m^2)

A_f : Coolant cross-sectional area (m^2)

A_s : Structure cross-sectional area (m^2)

A_i : Interface area (m^2)

B : Heat transfer coefficient increase with time ($W/m^{2o}C$)

C : Specific heat (J/kg^oC)

f : Friction factor

g : Gravitational acceleration (m/s^2)

g_r : Gravitational force per unit volume (radial direction) (N/m^3)

g_z : Gravitational force per unit volume (axial direction) (N/m^3)

h : Heat transfer coefficient ($W/m^{2o}C$)

H : Enthalpy (J/kg)

h_i : Interface heat transfer coefficient ($W/m^{2o}C$)

h_l : Head loss (m)

k : Loss coefficient

K : Thermal conductivity (W/m°C)

L : Length (m)

L_{eff} : Effective length (m)

Lt : Latent heat (J/kg)

m : Mass (kg)

P : Pressure (N/m^2)

Pe : Inertia pressure (N/m^2)

Pt : Total pressure (N/m^2)

Pv : Viscous pressure (N/m^2)

q : Heat flow (W)

Q : Flow rate (m^3/s)

Q1 : Heat flow at node 1 (W)

Q2 : Heat flow at node 2 (W)

t : Time(s)

T : Temperature (°C)

ρ : Density (kg/m^3)

μ : Viscosity (kg/ms)

τ : Shear stress (N/m^2)

Abstract of thesis submitted to the Senate of University Putra Malaysia in partial fulfilment of the requirements for the degree of Master of Science.

COMPUTER AIDED DESIGN AND ANALYSIS IN DIE/MOULD OF CASTING PROCESS

By

MD. SHAMSUL ABEDIN

September 1997

Chairman: Dr. Shamsuddin bin Sulaiman

Faculty: Engineering

Computer Aided Design (CAD) and Computer Aided Analysis (CAA) have been investigated and developed since the last twenty years as standalone systems. There is useful link between CAD and CAA in terms of data extraction from the graphics to non-graphics format for the analysis.

Computer Aided Design and Computer Aided Analysis packages have been developed incorporating AutoCAD for the fluid feeding progress and the thermal behaviour during the casting process. Network analysis process has been adopted for the current development. The Developed package includes the CAD graphics for design, transferring graphics to non-graphics and vice versa for pre-processing and post-processing for the Engineering Analysis.

The Developed package has been tested for the Die/Mould design for the proposed model. Finite element packages have been used for the prediction of the residual stresses of the Die/Mould.

Abstak tesis yang dikemukakan kepada Senet Universiti Pertanian Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

REKABENTUK TERBANTU KOMPUTER DAN ANALISIS DALAM ACUAN PROSES PENUANGAN

Oleh

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Rekabentuk Terbantu Komputer, CAD (computer aided design) dan Analisis Terbantu Komputer, CAA (computer aided analysis) telah dikaji, dan dibangunkan sejak dua puluh tahun yang lepas sebagai sistem-sistem berasingan. Terdapat hubungan yang rapat di antara CAD dan CAA dari segi pentukaran data dari grafik mahupun bukan grafik untuk membuat analisis.

Pakej CAD dan CAA telah dibina menggunakan AutoCAD untuk "fluid feeding progress" dan kelakuan haba dalam proses "Penuangan". Proses analisis rangkaian telah digunakan untuk kajian kini. Pakej yang direka memasukkan grafik CAD dalam rekabentuk, pertukaran dari grafik kepada bukan grafik dan sebaliknya untuk proses-sebelum dan proses-selepas analisis dalam kejuruteraan.

Pakej yang direka telah diuji manggunakan rekebentuk "die/mold" untuk model yang dicadangkan. Pakej unsur terhingga digunakan untuk membuat anggaran dalam "residual stresses" pada "die/mold".

CHAPTER I

INTRODUCTION

Project Background

Technical progress is very fast in the application of the computers to the manufacturing activities. Currently it is possible to computerise all the individual activities that make up a 'product cycle' from the demand for a product to its production. In this production cycle, design and analysis are the first steps among the successive steps of the cycle. So, design and analysis are the roots of the production cycle. Computer can perform repetitive jobs and lots of computational works very efficiently and quickly than human beings. So, it has become very effective to integrate computer to design and analysis processes. Computer integration in design and documentation helps to give the outlook of the generated idea by the designer. After visualising the design, the designer can modify his idea without too much effort as well as it can be presented as a final design. In Computer Aided Design (CAD), the designer can view the drafted design in different angles and sides.

For the analysis techniques such as finite difference, finite element, boundary element, hybrid and network element, the designer can extract the co-ordinate values and perform the computational effort by picking those co-ordinate values. This

possibility helps to reduce time constraint, as well as increase the accuracy of the calculation.

Computer Involvement in Design and Analysis

CAD involves any type of design activity, which makes use of the computer to develop, analyse or modify an engineering design. Modern CAD systems (some time integrated with CAD/CAM systems) are based on interactive computer graphics which denote a user-oriented system in which the computer is employed to create transformation, and display data in the form of picture or symbols (McMahon Chris and Browne Jimmie, 1993).

However, from the viewpoint of product design evaluation, the most important design phase is the conceptual design phase and the development of CAD systems to support work in this phase is desirable. Conceptual design phase includes much creative work, which is combined in a complex manner that appears to be creative/intelligent work at first glance (Arai and Kazuaki, 1992).

Computer aided engineering simplifies the creation of a database by permitting several applications to share the information in the database. These applications include finite difference, network approach and finite element analysis of stresses, strains, defections, fluid flow, temperature distribution in structures and load-bearing members and the generation, storage, and retrieval of NC data. Computer Aided Analysis systems are also used extensively in the design of

integrated circuits and other electronic devices (Kalpakjian, 1995 and Tay, A-O, 1997).

Integration of Computer Aided Design and Computer Aided Analysis

During the past recent years, industry has made a move to incorporate scientific techniques into die/mould design. Industries like to adopt a more systematic strategy; since the complexity of the parts to be cast has increased, the lead times have been reduced dramatically over the last decade. Many medium size and even small companies are now trying to incorporate computer aided design and computer aided manufacturing techniques in their design and manufacturing processes in an effort to reduce both the cost and time (Zhang et. al, 1996).

A computer aided analysis (CAA) system can be used to generate the initial process sequence (Altan, 1985), as well as increase the accuracy of the process. The basic calculations for generating each section in the sequence require the computation of areas and volumes for complex parts. Designers currently perform these computations manually while making approximation of certain sections of the part to simplify the problem. Thus, the conventional approach to Die/Mould design usually does not lead to very accurate results. Consequently, a reliable and practical engineering design technique would be useful. With the aid of Finite Element Method based analysis programs, the metal filling and heat transfer process can be simulated to identify and eliminate potential trouble spots in the process sequence.

Concept of Die/Mould Design in CAD

Die-casting is one of the most economical casting processes for manufacturing precision shaped parts in mass production. Die-cast component are being used increasingly in the automobile, aerospace, electronic and other industries because of their premium quality, low cost, and low weight (Allsop D. F. and Kennedy D., 1983).

The die casting industry is being challenged by the world marketplace to improve its manufacturing process continuously. To become more competitive, die casters have to reduce development time and improve quality. CAD/CAE technology has become an efficient tool for die casters to meet these increasingly (Zhang et. al, 1997).

From the general concept of the mould/die operation, it is important to design a mould/die that will safely absorb the forces of clamping, injection, and ejection. Furthermore, the flow conditions of the plastic path must be adequately proportional in order to obtain uniformity of product quality cycle after cycle. Finally, effective heat absorption from the molten metal by the Die/Mould has to be incorporated for a controlled rate of solidification prior to removal from the moulds (Peter, 1996).

Problem Definition and Scope of Work

Design, analysis and visualisation of the component are the most significant for the product design cycle. Design, design modification and documentation needs lot of time and intensive human labour. Commonly used analysis software needs to create data file for pre-processing. Visualisation process shows the data progress and outline of the generated results. Still there is not too much work on casting process to fulfil the above mentioned phases. Computer application of those phases eliminates tedious repetitive work and it is possible to generate almost accurate results depending on the complexity of the product.

CAD has become a standard tool in engineering design and analysis of manufacturing processes. At the design stage, it is normal way to develop a draught and carry out Finite Element Analysis (FEA) to assess the pressure in different stages of the element during the filling process and the temperature gradient in different segments depending on the initial metal temperature according to the feeding progress of engineering components.

Currently, many software packages are used during the phases of the design and development processes. Most of these tools are stand-alone analysis or test modules that are optimised to perform specific functions.

The main objective of this project is to develop a CAD/CAA system, which is an integration of CAD and CAA techniques for the casting process. It will mean, that a casting component can be drawn on a Visual Display Unit (VDU) screen and

the graphics data are then transferred from graphics to non-graphic format. These data known as pre-processing data will be arranged through the programming effort to run the Network Element programs for the fluid filling process and thermal behaviour of casting.

Objectives of the Present Work

The present study is focused on the Computer Aided Design and Computer Aided Analysis of Die/Mould of casting process, in this respect objectives of the current project are:

1. To find a way to create model drawings for Casting pattern and Die/Mould towards the direction of the integration of CAD and CAE.
2. To generate the meshes for the finite element analysis pre-processing input data and transfer the co-ordinate data from graphics to non-graphics format which will store all the information in a standard database for geometric calculation.
3. Analysis of the primary design is carried out using network approach for filling, solidification and temperature distribution in Mould/Die.
4. To draw graphs and contour for the post processing data for the prediction of the metal flow and thermal behaviour during the casting process.
5. Compare the simulated result for heat transfer by using different software currently available for the analysis.

Layout of Thesis

This thesis consists of seven chapters. The first chapter contains the introduction and aims of the research. Chapter II deals with the literature review, which includes topics, related to Computer Aided Design and Computer Aided Analysis and die/mould design.

Chapter III addresses the mathematical formulation of the network analysis of fluid flow and thermal aspects. Chapter IV caters for the development of the software for the pre and post processor.

In chapter V, results are shown for the model for fulfilling the objectives. Chapter VI concludes the overall development system and results and recommendations for future work.

CHAPTER II

LITERATURE REVIEW

In this chapter, important factors that are involved with data extraction, transfer, modelling and relevant works are reviewed for the integration of Computer Aided Design (CAD) and Computer Aided Analysis (CAA). In the area of Computer Application in Casting process, some work has been carried out on customising CAD, but very few work has been done related to metal filling, solidification and heat transfer process.

Recently, Zhang et. al, 1997 developed a CAD package for Die casting by customising CAD tools. The authors presented the P - Q2 technique which is based on the pumping rate capacity of die casting machine which can be used to predict the occurrence when a die is put on the machine. The authors showed the different pumping rates influencing the runner and gating system and predicted their location to achieve correct pressure and the flow rate.

Xinghong Li et. al, 1995 developed some tools on computer aided design system. They produced a multiview drawing showing isometric view in addition to the three principal views, all properly positioned, aligned and rendered for user interaction, and automated the production of the multiview drawing of a given solid.