Cairo University

SEMI-AUTOMATED GATING SYSTEM DESIGN WITH OPTIMUM GATE AND OVERFLOW POSITIONS FOR HPDC

By

Mohamed Refaat Abo El-Fotouh El-Basyony

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
MECHANICAL DESIGN AND PRODUCTION ENGINEERING

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Title of Thesis:

Semi-automated gating system design with optimum gate and overflow positions for HPDC

Key Words:
HPDC; Die Casting; Gating System

Summary:
This thesis studies HPDC die design, by developing a computer software that gives a fully detailed gating system dimensions with optimum gate and overflow locations to get a minimum porosity. Through, study the effect of part parameters i.e. width, length, height, thickness, angle, GSS and OSS on the porosity of the part. Furthermore, Four models developed as a part of software validation to ensure the results. These models covered both ZA 3 and Al 306 materials with one-cavity and two-cavity. However, models validated by both simulation and experimental models.

Acknowledgment

I would like to express my gratitude to my advisor, Prof. Dr. Abdel-Halim El-Habak, for his support, patience, and encouragement. His technical and editorial advice was essential to the completion of this thesis and has taught me innumerable lessons and insights on the workings of academic research in general.

It gives me great pleasure in acknowledging the support and help of Dr. Ahmed Yahia Shash.

I am grateful to my brothers Eng. Osama Refaat and my fellow Mahmoud Refaat, who have made available their support in a number of ways.

The friendship of Eng. Mahmoud Fahmy and his companionship and kind assistance are the key of success of this thesis.

I owe to my parents who given me opportunity for education from the best institutions and support throughout my life. I would like to express my deepest gratitude and love their dedication and the many years of support during my studies, that provided the foundation for this work.

Last, but not the least, I would like to thank my wife for her understanding and love during the past few years. Her support and encouragement was in the end what made this thesis possible.

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Abbreviation

CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CFD	Computer Fluid Dynamics
DOE	Design Of Experiment
FE	Finite Element
GA	Genetic Algorithm
GSS	Gate Shift Scale
HPDC	High Pressure Die Casting
NADCA	North America Die Casting Association
OSS	Overflow Shift Scale
QC	Quality Control
VOF	Volume of Fluid

Nomenclature

A_g	Ingate area of a cavity (mm^2)
A_m	Machine cast area (mm^2)
A_p	Part projected area (mm^2)
A_r	Runner area of a cavity (mm^2)
A_v	The min. area of the vent (mm^2)
D_p	Plunger diameter (mm)
J	The atomization factor
k	Empirically derived constant related to the die steel (sec/mm)
N_F	Max. number of cavities due to locking force
N_p	Max. number of cavities for each machine plunger
N_Q	Max. number of cavities due to flow rate
N_v	Max. number of cavities due to volume
Q_i	Flow rate of cavity (mm^3/sec)
Q_p	Max. machine plunger flow rate (mm^3/sec)
S	Percent solids at the end of fill
t	Max. filling time (sec)
T	Wall thickness (mm)
T_d	Die surface temperature just before the metal arrives (^oC)
T_f	Min. flow temperature of the metal alloy (^oC)
T_g	The ingate thickness (mm)
T_i	Metal temperature at the ingate (^oC)

v_g	The ingate velocity (mm/sec)
V_i	Volume of a cavity volume (mm^3)
V_m	Machine plunger volume (mm^3)
V_o	Overflow volume (mm^3)
v_p	Plunger speed (mm/sec)
V_p	Part volume (mm^3)
Z	Solids units conversion factor, degree to %
ρ	The density of the metal (N/mm^3)

Abstract

In High Pressure Die Casting (HPDC) the plunger speed and pressure are high. Therefore, the chance of having a porosity is high. This porosity eliminated by controlling HPDC process conditions (temperatures, plunger speed) and HPDC die gating system. Die casters usually carry out a die casting test before producing new castings. At the die-casting test stage, the runner and gate parts always repeatedly corrected to eliminate porosity, which leads to a lengthened processing time and increased processing cost.

Many studies tried to get the optimum gating system but for a certain case study. None of them gave a generalized solution for any case or part dimensions. That is because of the complexity of the process and the required experience. Although there are some books tried to make some standard formulas as a design base for the gating system, but still the experience of the die designer is the key of success for every case. Laterally some simulation software began to be a powerful tool for die designer, but still these softwares does not give any recommendations for gating system design it just give the result of your experienced design. However, this save a lot of time and cost but still the gating system design depend on the expertise of the die designer, add to this that the cost of these softwares are high and required a Computer Fluid Dynamics (CFD) background.

In this study, a Visual Basic computer software developed to determine the gating system design with optimum gate and overflow positions for Cold Chamber High Pressure Die-Casting (HPDC) die design by setting the part dimensions and choosing the suitable machine from a pre-defined database in the software. The software used some North America Die Casting Association (NADCA) formulas as a base for the gating-system design and formulate the experts' reviews into other relation and methods to optimize gating-system. A design of experiment used to formulate the objective function of the gate and overflow optimum position using Box-Behnken design of experiment method. The study also used ProCAST simulation software for both design of experiment and validation. At the end of this study, four models developed using simulation and a physical die casting as a part of the software validation. The results showed that the developed software could determine the gating system design and eliminate the correction in the test stage without high experienced die design designer.