Optimal System Design with Geometric Considerations

by

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TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

Table

LIST OF SYMBOLS

$\mathbf{d}_i$	vector of all dimensions of component i;size of vector d_i can vary depending on i
$\mathbf{x}_g$	design variable vector for optimization problem for packaging
$\mathbf{x}_p$	design variable vector for optimization problem for functionality
C_i,C_c	geometric space occupied by i-th component and container, respectively; they are sets of points
$C_i \cap C_j$	intersection of C_i and C_j
d_{ij}	j-th dimension of component i
f_g	objective function for optimization problem for packaging
f_p	objective function for optimization problem for functionality
i	index for i-th component; i=1,...,N
L_{pipe_i}	length of i-th pipe
L_{pipe}	total length of pipes
N	number of components
N_{pipe}	number of pipes
P_{comp}	power consumed by component
Ti	Tower i; i=1,2
$TiCAC$	charge air cooler in tower i
$TiFan$	fan in tower i
$TiPj$	pump j in tower i
$TiRj$	radiator j in tower i
$Vol(C_i)$	volume of C_i

Running Example

$\dot{m}$	mass flow rate
$\dot{V}$	volumetric flow rate
A	area
a, b, c	pressure drop coefficients
C	heat capacity rate
C_f	friction coefficient
C_p	specific heat
C_r	the ratio of minimum to maximum fluid heat capacity rate (C_{min}/C_{max})
d	diameter
f	friction factor
H	height
h	convection heat transfer coefficient
I	electric current
K_{loss}	loss coefficient
L	length
N	number of revolutions per minute (rpm)
NTU	number of transfer units
p	pressure
q	heat generation rate per heat transfer rate
Re	Reynolds number
T	temperature
t	thickness
U	overall heat transfer coefficient
V	voltage
α	scale factor
ϵ	effectiveness of heat exchanger

η	efficiency
μ	dynamic viscosity
ω	angular velocity
ρ	density
σ	Stefan-Boltzmann constant
τ	torque

Subscripts and Superscripts in Running Example

act	active area
air	air
c	cold
CAC	charge air cooler
cap	capacity
co	coulomb
$comp$	component
$cond$	condenser
$cool$	coolant
eng	engine
ext	external
gen	generator
h	hot
$heat$	heat source
i	input
int	internal
$louv$	louver
min	minimum
mot	motor
o	output

oil	oil cooler
pb	power bus
r	ratio
rad	radiator
ref	reference
T/S	thermostat
tc	turbo charger

ABSTRACT

Optimal System Design with Geometric Considerations

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System design is tied to both functionality and geometric realization. The former is pertinent to system performance, and the latter is related to packaging. Packaging is an optimization process that finds a desirable placement for the system components within a given space. When the components do not fit into the allocated space at the packaging stage, the design engineers must make modifications that can affect the performance of the system. The modification of a component can also affect the geometry and positions of other components in the system. These changes might lead to an infeasible layout. Therefore, optimizing the system performance considering packaging is desirable.

Packaging problems and solution methods have been studied in many applications, such as electrical circuit layout, glass or metal cutting, truck loading, trunk packing, rapid prototyping (RP), architectural floor plan layout, routing, and mechanical component layout. Packaging problems in a mechanical system design are more challenging than 2D applications such as circuit layout and the metal cutting problem; this is due to a larger design space and increased complexity of geometry. Complex 3D geometry leads to increased computational time for interference checking,

which is inevitable for finding a feasible layout. Detailed 3D CAD models, however, are not required or not available at the preliminary design stage. Therefore, abstract representation of the components is necessary during the layout process. Abstract models should balance accuracy of geometry representation and rapid computation capturing designers intent.

This dissertation presents a computational environment for addressing the combined packaging and optimal system design. The packaging problem also includes pipe generation because pipe routing is also important problems in mechanical system design. The simulation model of a thermal management system for heavy duty series hybrid electric vehicles is used to demonstrate the usefulness of the proposed framework.