文章编号: 1001－2060(2004)03－0292－03

热力系统新型纵流壳程换热器 CAD 技术研究

刘敏珊, 董其伍, 古　新
(郑州大学 热能工程研究中心, 河南　郑州　450002)

摘　要: 通过对新型纵流壳程换热器 CAD 系统的参数化图形设计、数据结构及处理和系统集成等关键技术的研究, 实现了新型纵流壳程换热器工艺、机械和零部件 CAD 的集成化, 解决了信息集成和总装图集成这两个关键问题。该系统可大大提高设计效率与设计质量, 为新型纵流壳程换热器的进一步研究与推广提供了方便。

关　键　词: 热力系统; 新型纵流壳程换热器; 参数化图形设计; 信息集成; 总装图集成

中图分类号: TK172; TP302　　文献标识码: A

1　引　言

随着计算机技术的迅速发展和普及, 计算机辅助设计(Computer Aided Design)及绘图的理论与应用技术得到了越来越广泛的应用。而目前在化工、炼油、轻工、动力、冶金及环保等领域广泛应用的热力系统换热设备的设计过程复杂, 为提高设计效率和质量, 需开发出相应的一体化 CAD 系统。因此, 本文将 CAD 技术与换热设备设计, 特别是与新型纵流壳程换热器的设计相结合, 以 AutoCAD 应用软件的运行环境为基础, 形成一个只需输入少量工艺参数即可输出性能优异的换热设备全部设计资料的大型软件包, 即换热器 CAD 系统 HECAD(Heat exchanger CAD), 实现了热力系统换热设备从工艺、机械、零部件到设备总图的一体化和集成化设计, 从而有效提高换热设备的设计效率和质量, 加快其开发和推广步伐。

2　HECAD 系统概况

新型纵流壳程换热器 CAD 系统, 其结构如图 1 所示。图中所示的子系统或模块不仅可以独立运行, 单独进行换热设备的工艺设计、机械设计和零部件设计, 而且还可以通过信息传递实现工艺设计、机械设计、零部件设计到设备施工图等设计的集成, 特别是首次完成了新型纵流壳程换热器的非标准结构设计。

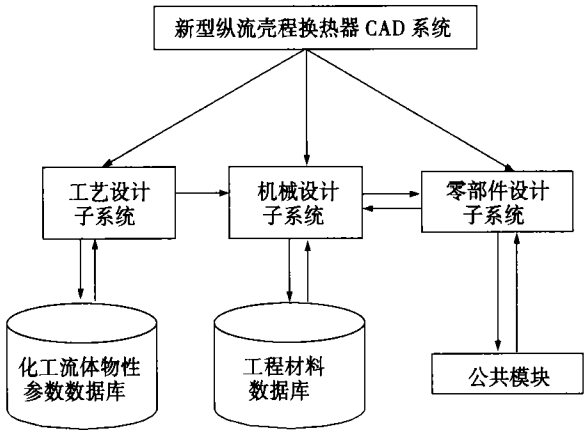

图 1　HECAD 系统的总体结构图

3　系统开发中的关键技术

围绕系统的开发, 主要研究 CAD 技术在热力系统新型高效换热设备设计中的应用等问题, 实现了各子系统数据表示的一致性、开发平台的统一性和信息的准确性, 研究出了适合于化工设备 CAD 系统的开发模式与成套技术。

3.1　参数化设计技术

实现参数化图形设计是 CAD 的核心任务之一。参数化图形设计, 就是将图形的尺寸与一定的设计条件(或约束条件)相关联, 即将图形的尺寸看成是"设计条件"的函数, 当设计条件发生变化时, 图形尺寸便会随之得到相应更新。参数化图形设计是相对于交互式绘图而言的, 早期的 CAD 系统只提供交互式绘图功能, 交互式绘图只能是手工绘图的简单替代, 只有参数化图形设计才能发挥 CAD 准确、快速的特点。

收稿日期: 2002－06－18
作者简介: 刘敏珊(1943－), 女, 河南商丘人, 郑州大学教授, 博士生导师。

系统参数化设计的主要工作是进行二维参数化图形设计，其基本手段主要有尺寸驱动法和程序驱动法两种。前者适用于结构相对简单的零件设计，从表面上看此法类似于绘图软件本身具有的参数化功能，首先由应用程序生成所设计零件的基图，用户可以修改基图的尺寸，然后应用程序一次性更新，生成新图。而对于结构相对较为复杂，尺寸较多的零部件 设计，宜于采用程序驱动法，将零部件设计过程中的所有关系式均融入到应用程序之中，在程序的控制下，顺序执行这些设计表达式，生成参数化图形。

3.2　界面设计技术

界面是用户与 CAD 系统进行信息交流的一种接口，用户通过界面 CAD 系统表达其意图，如调用命令、输入数据等，图形系统也通过界面显示当前执行情况，请示下一步工作或回答用户的提问等。系统集成在 AutoCAD 环境下，总体界面以 AutoCAD 系统的界面为基础，采用以对话框为主，菜单、工具栏、快捷键、命令操作等为辅的用户界面形式，从 AutoCAD 的菜单中的 HECAD 用户菜单按钮项中引出，如图 2 所示。

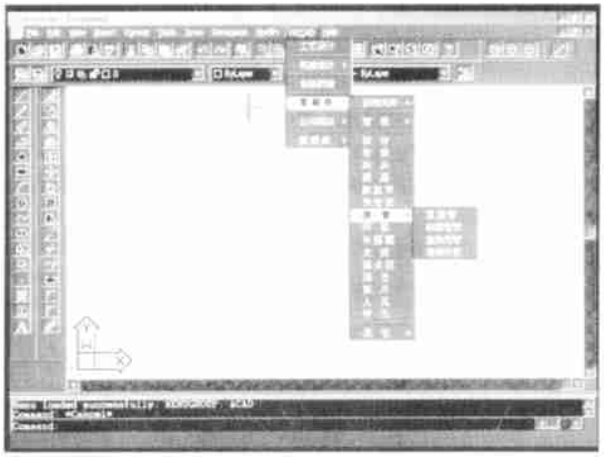

图 2　AutoCAD 菜单中的 HECAD 系统

考虑系统界面设计风格的一致性，以及与系统功能、结构的配套性等，根据系统的模块组织结构，设计出了系统用户界面导航图，然后根据导航图绘制出所有用户界面的设计草图，再根据设计草图，按照系统的分工编写各自相应的程序。

系统用户界面的设计主要采用：AutoCAD 系统的定制技术(如：菜单编写技术、工具条定制技术、命令修改和添加技术)、基于 MFC 的可视化界面设计技术、Dialogue Control Language 编程技术、AutoCAD Run-time extension 驱动技术等。

3.3　数据结构及数据处理技术

在热力系统换热设备的设计过程中，需要从有关的工程手册或设计规范中查取大量的数据，这些数据多以线图或数据表格的形式给出，在实现 HECAD 系统时需将这种人工查取转变为 CAD 进程中的高效、快速处理。热力系统的换热设备 CAD 系统的数据信息传递如图 3 所示。

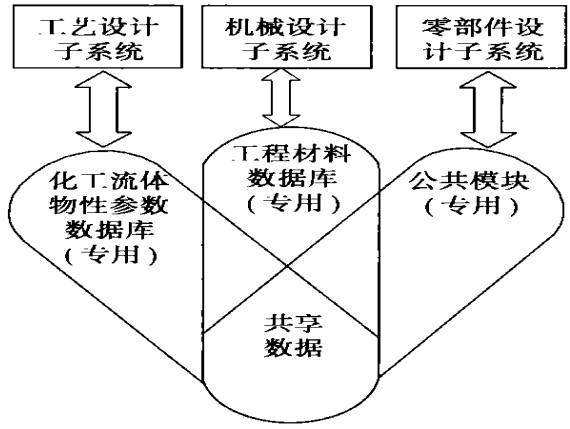

图 3　HECAD 系统的数据信息传递示意图

运用数据结构的原理和方法，系统采用文件、线性表、树等几种数据结构的形式。系统数据的控制常采用控制字或关键字。例如：当用户从某对话框的列表框中选定一个压力值的时候，系统便将该压力值在列表框中的序号作为控制字去控制打开对应此压力值的数据文件。然后再根据用户选择的公称直径作为关键字，在打开的数据文件中找到相应的记录。还可通过用户对系统某个对话框所进行的某项操作而引发的 Windows 消息，来控制产生某些动作，如打开数据文件读取数据或在对话框在某些构件(如编辑框、列表框等)中显示相应的数据。

3.4　系统集成技术在系统中的应用研究

HECAD 系统的最终目的是得到设备总装图和必要的零部件图，为此需把各个子系统和模块有机地集成起来，以工艺设计子系统、机械设计子系统和零部件设计子系统为主线，而化工流体物性参数数据库、工程材料数据库和公共模块为系统集成服务。这样，在各子系统、模块之间必然存在着信息交流以及怎样通过集成得到总装图两个关键问题，这两个问题是整个系统的核心。

3.4.1　信息集成

信息集成的主要工作是信息的管理与传递。首先必须形成一个数据集中管理的环境,HECAD 系统的数据信息分为共享数据(如结构设计参数、图形信息等)和专用数据(如化工流体物性参数数据库为工艺设计子系统的专用数据)两大类,采用线性表、结构体等形式进行信息管理。对每个模块的设计结果建立一个数据文件放入共享库以方便其它模块和子系统的取用,其它子系统在读取时亦按结构体的方式来读。数据信息可通过界面由用户输入或通过各子系统的设计结果继承。

3.4.2 总装图集成

考虑不同用户的需要,HECAD 系统总装图的集成采用了两种方式:

(1) 单元拼装式

HECAD 系统建立了庞大的热力系统换热设备设计中使用的标准零部件和非标准零部件的参数化图库。该图库同时满足零部件图和设备总图的需要,用户只需在操作界面上选择"零部件图"或"总装图"即可得到满足要求的图形,只需从工艺设计子系统的用户界面上输入必要的设计条件(系统所有用户界面的输入均不超过一屏),即可依次进行零部件的机械设计,设计好的零部件即可作为一个单元拼画在总装图上,零部件的其它信息同时进入总图集成环境,以备生成相关的内容与文档,如明细栏等。

(2) 整体参数化

为了提高总装图的生成速度,把一些成熟结构的设备进行整体参数化设计,即面向设备的设计。用户只需从工艺设计子系统的用户界面中输入必要的设计条件,系统自动完成工艺设计、机械设计和零部件设计等,同时生成设备的总装图。

系统为用户提供了一套总图集成工具,如:系统初始化模块、技术要求自动标注模块、图框标题栏自动生成模块、装配图自动消隐模块、明细表自动生成模块、管口表自动生成模块、技术特性表自动生成模块等。这套工具中的大部分模块还可以作为 AutoCAD 系统的补充工具使用,为不使用 HECAD 系统的一般 AutoCAD 用户提供了国标化的工具包。

4 结束语

(1) 系统实现了新型纵流壳程换热器工艺、机械、零部件 CAD 的集成化,尤其是首次实现了新型纵流壳程换热器关键部件的系列化计算机辅助设计。

(2) 零部件设计中新、旧标准并存,所有结构参数均列入用户界面的编辑框,均设有默认值,并配有结构简图,方便、直观。可同时实现标准和非标准零部件的设计。

(3) 对新型纵流壳程换热器计算机辅助设计过程中遇到的大量不同类型的线图、数表进行了有效的程序化处理,使数据取用极为方便,提高了速度,节约了存储空间。

(4) 有待将 CAD 技术与 CAE、CAM 技术结合起来,实现 CAD/CAE/CAM 集成化设计,从而进一步提高新型纵流壳程换热器设计和生产的自动化程序,减少投资费用。

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Thermal Energy Engineering, Tsinghua University, Beijing, China, Post Code: 100084) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(3). — 281 ~ 284

Radiation energy signals are capable of more directly reflecting the variation of fuel flow rate or combustion quality. An optimization system of radiation energy detection-based intelligent combustion-evolution has been set up to implement the evolution-optimization adjustment of the parameters of a thermodynamic control system. A combustion optimization circuit was designed, which consists of two parts: a fuzzy self-optimizing controller of flue-gas oxygen content and furnace total radiation energy, and an air/coal ratio evolution optimizer. The results of a simulation and the on-site operation results at Kaiyuan Thermal Power Plant have demonstrated the practicality and superiority of the adopted method. **Key words**: furnace radiation energy, evolution optimization

喷水塔饱和器的动态建模与仿真= **Dynamic Modeling and Simulation of a Water-spray Tower Saturator** [刊, 汉] / LIU Yong-wen, SU Ming, WENG Shi-lie (Education Ministry Key Laboratory for Power Machinery & Engineering under the Shanghai Jiaotong University, Shanghai, China, Post Code: 200030) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(3). — 285 ~ 287

A method of building a one-dimensional dynamic model for a water-spray tower saturator is discussed. Under this method the saturator has been divided along its height into several segments, each being represented by gas and water-drop modules. The setting-up of an explicit simulation model makes it possible to clarify the variation mechanism of parameters of the saturator under a steady state and during a dynamic process. According to the data of the model under a steady state the variation of pressure along the main flow direction of gas basically assumes a linear relationship, while the variation of other parameters has been found to be nonlinear. The results of the model dynamic simulation indicate that the interaction between gas pressure and water in the saturator features a rapid process, thus exhibiting the characteristics different from those of a heat exchanger. **Key words**: humid air turbine, saturator, dynamic simulation

熔融碳酸盐燃料电池动态性能数值模拟= **Numerical Simulation of the Dynamic Performance of Molten Carbonate Fuel Cells** [刊, 汉] / YU Li-jun, JIANG Xiu-min, YUAN Jun-qi (Institute of Mechanical & Power Engineering under the Shanghai Jiaotong University, Shanghai, China, Post Code: 200240), CAO Guang-yi (Fuel Cell Research Institute under the Shanghai Jiaotong University, Shanghai, China, Post Code: 200030) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(3). — 288 ~ 291

A dynamic three-dimensional mathematical model of fuel cells featuring variable parameters was set up, which can give an accurate description of heat generation, mass transfer and electrochemical reaction characteristics. By using a numerical simulation method it is possible to forecast such performance properties as fuel cell temperature and speed distribution, etc. Through an experimental investigation test data, such as fuel cell power-generation system output performance and temperature distribution, etc can be acquired. The comparative analysis of numerical calculation results with those of experimental tests has confirmed the precision of the numerical simulation, testifying to the relatively high reliability of the adopted mathematical model. **Key words**: fuel cell, computational fluid mechanics, numerical simulation

热力系统新型纵流壳程换热器 CAD 技术的研究= **Research and Application of CAD Technology for a New Type of Heat Exchanger with a Longitudinal Flow of Shell-side Fluid in a Thermodynamic System** [刊, 汉] / LIU Min-shan, DONG Qi-wu, GU Xin (Thermal Energy Control Center under the Zhengzhou University, Zhengzhou, China, Post Code: 450002) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(3). — 292 ~ 294

Through the research on some key items of CAD technology, such as parametric graphic design, data configuration and processing, and system integration, etc implemented was the CAD technology integration for a new type of tubular heat exchanger with a longitudinal flow of the shell-side fluid (NTTHELFSF). The CAD technology integration entails fabrication technology, machine components and parts. In addition, resolved were two key issues, namely, information integration and general assembly drawing integration. As a result, it is possible to dramatically enhance the design efficiency and quality of the NTTHELFSF, blazing a new path for the further research and popularization of the latter. **Key words**: thermodynamic system, new type of tubular heat exchanger with a longitudinal flow of shell-side fluid, parametric graphic

design, information integration, general assembly drawing integration.

基于谐波小波变换的 4—73 风机压力侧失速特性分析＝**An Analysis of Pressure-side Stalling Characteristics of a 4-73 Air Fan Based on Harmonic Small-wave Transformation** [刊, 汉] / WANG Song-ling, HOU Jun-hu, AN Lian-suo (Power Engineering Department, North China Electric Power University, Baoding, China, Post Code: 071003) // Journal of Engineering for Thermal Energy &Power. — 2004, 19(3). — 295～298, 315

Based on a qualitative analysis of the pressure-side stalling formation mechanism of a centrifugal fan, the authors have through an experimental study of 4-73 air fan discovered the pressure-side stalling phenomenon of the latter. The time-frequency characteristics of the pressure-side stalling are analyzed by using a harmonic small-wave transformation. During the analysis the orthogonal harmonic small waves, which have a relatively poor time-domain locating ability, underwent a frequency-domain smoothing processing. In the analysis of the rotating stall introduced was a non-orthogonal harmonic small-wave transformation. The results of the analysis have demonstrated the effectiveness of harmonic small-wave transformation for analyzing the rotating stall characteristics of centrifugal fans. **Key words**: centrifugal fan, harmonic small wave, rotating stall, characteristics analysis

船用锅炉方形翅片管经济器的试验与应用＝**Experimental and Applied Research of the Square Finned-tube Economizer of a Marine Boiler** [刊, 汉] / LIU Xiang-yuan, LI Yu-hong, WU Xiao-bing (Thermal Energy Engineering Department, Tsinghua University, Beijing, China, Post Code: 100084), JIANG Xiao-yan (Naval Materiel Research and Demonstrative Center, Beijing, China, Post Code: 100073) // Journal of Engineering for Thermal Energy &Power. — 2004, 19(3). — 299～301

A discussion is conducted regarding the necessity to upgrade a marine main boiler economizer along with the analysis of the application circumstances and merits of square finned tubes. On a heat-transfer wind tunnel test rig an experimental research of the air-side flow resistance and heat transfer was performed of square finned tube banks. The results of the research indicate that in case of air speed greater than 25 m/s it is necessary to revise heat transfer factors through tests. Finally, a rational design scheme was decided for the economizer with square finned tubes on the basis of the test results. **Key words**: marine boiler, economizer, square finned tube

火电厂单元制循环水系统离散优化模型及应用＝**A Discrete Optimized Model for the Monobloc Configured Circulating Water System of a Thermal Power Plant and Its applications** [刊, 汉] / HUANG Xin-yuan, ZHAO Li, AN Yue-li (College of Energy and Power Engineering under the Shandong University, Jinan, China, Post Code: 250061), CHANG Jia-xing (Huangtai Power Station, Jinan, China, Post Code: 250100) // Journal of Engineering for Thermal Energy &Power. — 2004, 19(3). — 302～305

A discrete optimized model was proposed for a monobloc configured circulating water system featuring non-continuous change of water flow rate. By conducting iterative calculations of equivalent profit points the model can determine the critical operating conditions at the juncture of switch-over of circulating-water pumps. With the power unit No. 7 of the Huangtai Power Station serving as an example the present model was used to study operation optimization in order to determine the most economical grouping-mode of operation for the circulating water pumps at different seasons and at various loads of the power unit. A profit analysis indicates that for a 300 MW power unit through the introduction of discrete optimization for a circulating water system it is possible to achieve a reduction of coal consumption by 0.5 - 0.7 g/(kWh). On the basis of thermodynamic test data an empiric formula is determined for the heat transfer factor of a steam condenser, which can serve as a guide for other similar units. **Key words**: circulating water system, discrete optimization, economic operation

充气热管空气预热器的设计分析及应用＝**Design Analysis and Application of a Gas-filled Heat-pipe Air Preheater** [刊, 汉] / SHI Cheng-ming, HU Hui-li, LI Ling-bo (College of Power Engineering under the Chongqing University, Chongqing, China, Post Code: 400044) // Journal of Engineering for Thermal Energy &Power. — 2004, 19(3). — 306～308