特别说明

Heat Treatment of Die and Mould Oriented Concurrent Design

LI Xiong,ZHANG Hong-bing,RUAN Xue—yu,LUO Zhong—hua,ZHANG Yan

Abstract:

Many disadvantages exist in the traditional die design method which belongs to serial pattern. It is well known that heat treatment is highly important to the dies. A new idea of concurrent design for heat treatment process of die and mould was developed in order to overcome the existent shortcomings of heat treatment process. Heat treatment CAD/CAE was integrated with concurrent circumstance and the relevant model was built. These investigations can remarkably improve efficiency, reduce cost and ensure quality of R and D for products.

Key words:die design; heat treatment; mould

Traditional die and mould design,mainly by experience or semi—experience, is isolated from manufacturing process.Before the design is finalized, the scheme of die and mould is usually modified time and again, thus some disadvantages come into being,such as long development period,high cost and uncertain practical effect.Due to strong desires for precision,service life,development period and cost,modern die and mould should be designed and manufactured perfectly.Therefore more and more advanced technologies and innovations have been applied,for example,concurrent engineering,agile manufacturing virtual manufacturing,collaborative design,etc.

Heat treatment of die and mould is as important as design,manufacture and assembly because it has a vital effect on manufacture, assembly and service life. Design and manufacture of die and mould have progressed rapidly, but heat treatment lagged seriously behind them. As die and mould industry develops, heat treatment must ensure die and mould there are good state of manufacture, assembly and wear—resistant properties by request.

Impertinent heat treatment can influence die and mould manufacturing such as over—hard and—soft and assembly. Traditionally the heat treatment process was made out according to the methods and properties brought forward by designer. This could make the designers of die and mould and heat treatment diverge from each other, for the designers of die and mould could not fully realize heat treatment process and materials properties, and contrarily the designers rarely understood the service environment and designing thought. These divergences will impact the progress of die and mould to a great extent. Accordingly, if the process design of heat treatment is considered in the early designing stage, the aims of shortening development period, reducing cost and stabilizing quality will be achieved and the sublimation of development pattern from serial to concurrent will be realized.

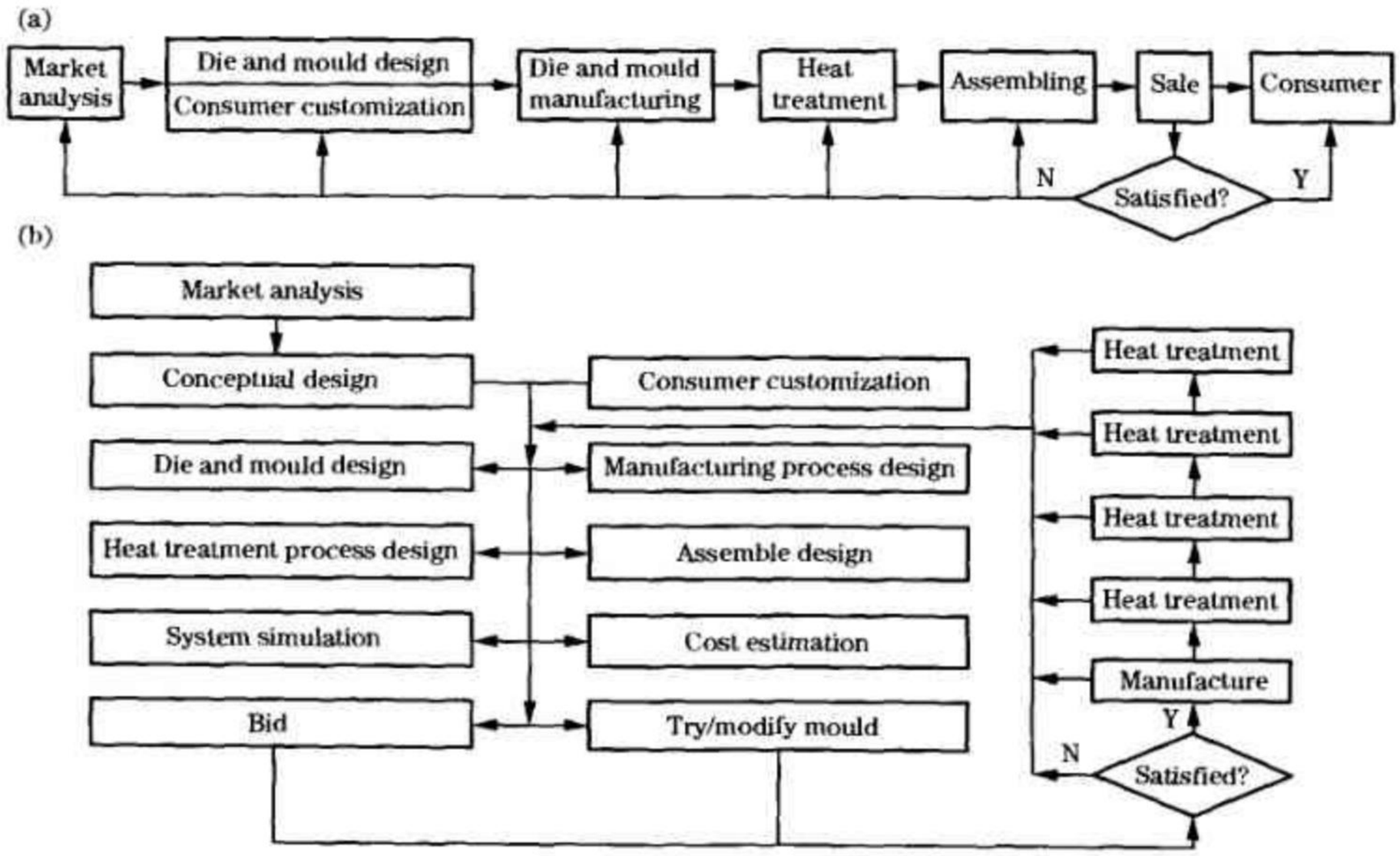
Concurrent engineering takes computer integration system as a carrier,at the very start subsequent each stage and factors have been considered such as manufacturing, heat treating, properties and so forth in order to avoid the error. The concurrent pattern has dismissed the defect of serial pattern,which bring about a revolution against serial pattern.

In the present work. the heat treatment was integrated into the concurrent circumstance of the die and mould development, and the systemic and profound research was performed.

1 Heat Treatment Under Concurrent Circumstance

The concurrent pattern differs ultimately from the serial pattern(see Fig. 1).With regard to serial pattern, the designers mostly consider the structure and function of die and mould, yet hardly consider the consequent process, so that the former mistakes are easily spread backwards. Meanwhile, the design department rarely communicates with the assembling, cost accounting and sales departments. These problems certainly will influence the development progress of die and mould and the market foreground. Whereas in the concurrent pattern, the relations among departments are close, the related departments all take part in the development progress of die and mould and have close intercommunion with purchasers. This is propitious to elimination of the conflicts between departments, increase the efficiency and reduce the

cost.



(a) Serial pattern; (b) Concurrent pattern

Fig. 1 System frame chart of serial and concurrent engineering based die and mould exploitation

Heat treatment process in the concurrent circumstance is made out not after blueprint and workpiece taken but during die and mould designing. In this way, it is favorable to optimizing the heat treatment process and making full use of the potential of the materials.

2 Integration of Heat Treatment CAD / CAE for Die and Mould

It can be seen from Fig. 2 that the process design and simulation of heat treatment are the core of integration frame. After information input via product design module and heat treatment process generated via heat treatment CAD and heat treatment CAE module will automatically divide the mesh for parts drawing, simulation temperature field microstructure analysis after heat—treatment and the defect of possible emerging (such as overheat,over burning), and then the heat treatment process is judged if the optimization is made according to the result reappeared by stereoscopic vision technology. Moreover tool and clamping apparatus CAD and CAM are

integrated into this system.

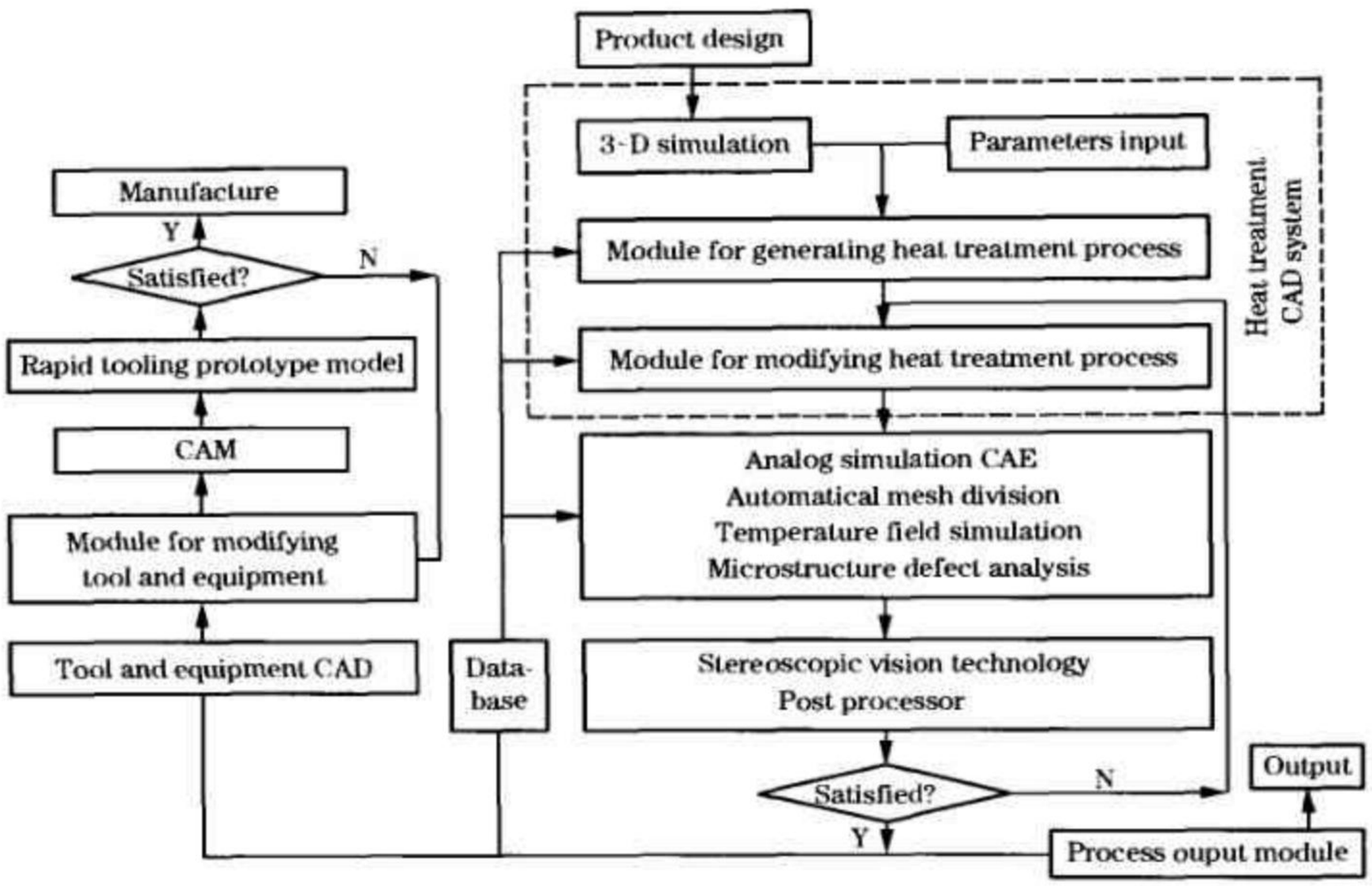


Fig. 2 System frame chart integrating heat treatment CAD/CAE for concurrent engineering

The concurrent engineering based integration frame can share information with other branch. That makes for optimizing the heat treatment process and ensuring the process sound.

2.1 3-D model and stereoscopic vision technology for heat treatment

The problems about materials, structure and size for die and mould can be discovered as soon as possible by 3-D model for heat treatment based on the shape of die and mould. Modeling heating condition and phase transformation condition for die and mould during heat treatment are workable, because it has been broken through for the calculation of phase transformation thermodynamics, phase transformation kinetics, phase stress,thermal stress, heat transfer, hydrokinetics etc. For example, 3-D heat —conducting algorithm models for local heating complicated impression and asymmetric die and mould, and M ARC software models for microstructure

transformation was used. Computer can present the informations of temperature, microstructure and stress at arbitrary time and display the entire transformation procedure in the form of 3-D by coupling temperature field,microstructure field and stress field. If the property can be coupled,various partial properties can be predicted by computer.

2.2 Heat treatment process design

Due to the special requests for strength, hardness, surface roughness and distortion during heat treatment for die and mould, the parameters including quenching medium type, quenching temperature and tempering temperature and time, must be properly selected, and whether using surface quenching or chemical heat treatment the parameters must be rightly determined. It is difficult to determine the parameters by computer fully. Since computer technology develops quickly in recent decades,the difficulty with large—scale calculation has been overcome. By simulating and weighing the property, the cost and the required period after heat treatment. it is not difficult to optimize the heat treatment process.

2.3 Data base for heat treatment

A heat treatment database is described in Fig. 3. The database is the foundation of making out heat treatment process. Generally, heat treatment database is divided into materials database and process database. It is an inexorable trend to predict the property by materials and process. Although it is difficult to establish a property database, it is necessary to establish the database by a series of tests. The materials database includes steel grades,chemical compositions, properties and home and abroad grades parallel tables. The process database includes heat treatment criterions, classes, heat preservation time and cooling velocity. Based on the database, heat treatment process can be created by inferring from rules.

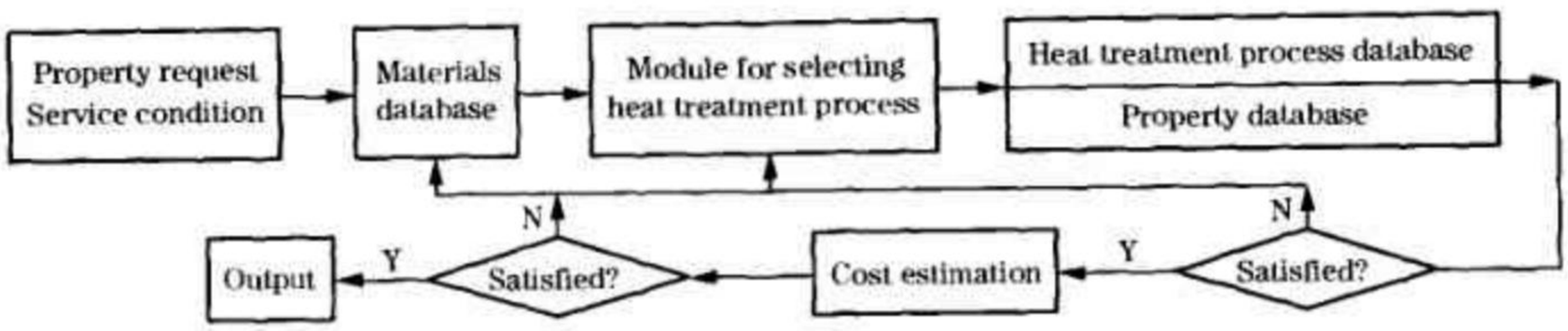


Fig. 3 Heat treatment database

2.4 Tool and equipment for heat treatment

After heat treatment process is determined, tool and equipment CAD / CAE system transfers the information about design and manufacture to the numerical control device. Through rapid tooling prototype, the reliability of tool and the clamping apparatus can be judged. The whole procedure is transferred by network, in which there is no man—made interference.

3 Key Technique

3.1 Coupling of temperature, microstructure, stress and property

Heat treatment procedure is a procedure of temperature-microstructure—stress interaction. The three factors can all influence the property (see Fig. 4). During heating and cooling, hot stress and transformation will come into being when microstructure changes.Transformation temperature-microstructure and temperature—microstructure—and stress-property interact on each other. Research on the interaction of the four factors has been greatly developed,but the universal mathematic model has not been built. Many models fit the test nicely, but they cannot be put into practice. Difficulties with most of models are solved in analytic solution, and numerical method is employed so that the inaccuracy of calculation exists.

Even so, comparing experience method with qualitative analysis, heat treatment simulation by computer makes great progress.

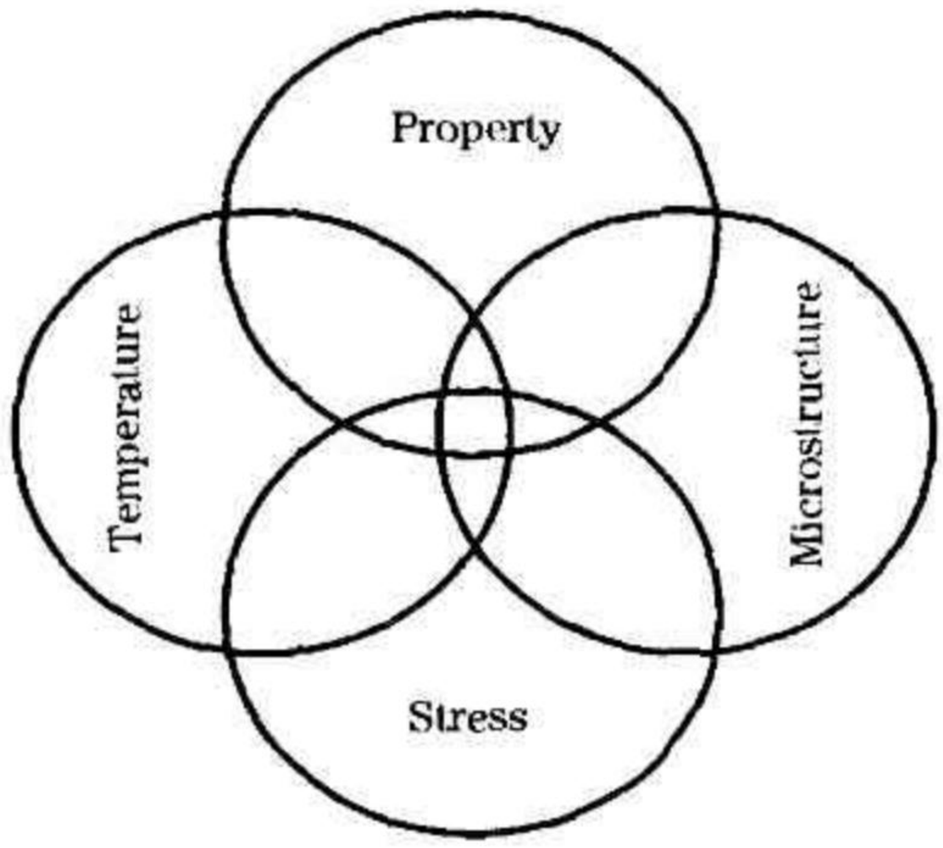


Fig. 4 Illustration of heat treatment progress

3.2 Establishment and integration of models

The development procedure for die and mould involves design,manufacture, heat treatment, assembly, maintenance and so on. They should have own database and model. They are in series with each other by the entity—relation model. Through establishing and employing dynamic inference mechanism , the aim of optimizing design can be achieved. The relation between product model and other models was built. The product model will change in case the cell model changes. In fact, it belongs to the relation of data with die and mould. After heat treatment model is integrated into the system, it is no more an isolated unit but a member which is close to other models in the system. After searching, calculating and reasoning from the heat treatment database,procedure for heat treatment, which is restricted by geometric model,manufacture model for die and mould and by cost and property, is obtained. If the restriction is disobeyed, the system will send out the interpretative warning.

All design cells are connected by communication network.

3.3 Management and harmony among members

The complexity of die and mould requires closely cooperating among

item groups. Because each member is short of global consideration for die and mould development, they need to be managed and harmonized. Firstly,each item group should define its own control condition and resource requested,and learn of the request of up-and-down working procedure in order to avoid conflict. Secondly, development plan should be made out and monitor mechanism should be established. The obstruction can be duly excluded in case the development is hindered.

Agile management and harmony redound to communicating information, increasing efficiency, and reducing redundancy. Meanwhile it is beneficial for exciting creativity, clearing conflict and making the best of resource.

4 Conclusions

(1) Heat treatment CAD / CAE has been integrated into concurrent design for die and mould and heat treatment is graphed,which can increase efficiency, easily discover problems and clear conflicts.

(2) Die and mould development is performed on the same platform. When the heat treatment process is made out, designers can obtain correlative information and transfer self-information to other design departments on the platform.

(3) Making out correct development schedule and adjusting it in time can enormously shorten the development period and reduce cost.

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LI Xiong,ZHANG Hong-bing,RUAN Xue—yu,LUO Zhong—hua,ZHANG Yan. Heat Treatment of Die and Mould Oriented Concurrent Design[J]. Journal of Iron and Steel Research, 2006,13(1):40-43, 74

模具热处理及其导向平行设计

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摘要：

在一系列方式中，传统模具设计方法存在许多缺点。众所周知，热处理对模具起着非常重要的作用。为了克服模具热处理工艺存在的缺点，一种新的模具热处理工艺并行设计方法已经被开发出来了。热处理 CAD/CAE 技术是集成了并行环境和有关模型而建立的。这些调查研究可以显著提高效率，降低成本，并保证产品质量达到 R 和 D 级。

关键词： 模具设计；热处理；模具

传统模具设计主要是依照自身实践经验或依照部分实践经验，而不是制造工艺。在设计完成之前，模具方案通常要被一次又一次的改进，于是有些缺点便出现，例如开发时期长，成本高和实际效果不明显。由于对精确性、使用寿命、开发期和费用的严格要求，先进的模具要求设计和制造得十分完善。因此越来越先进的技术和创新方法被应用其中，例如并行工程、敏捷制造业、虚拟制造业、协同合作设计等。

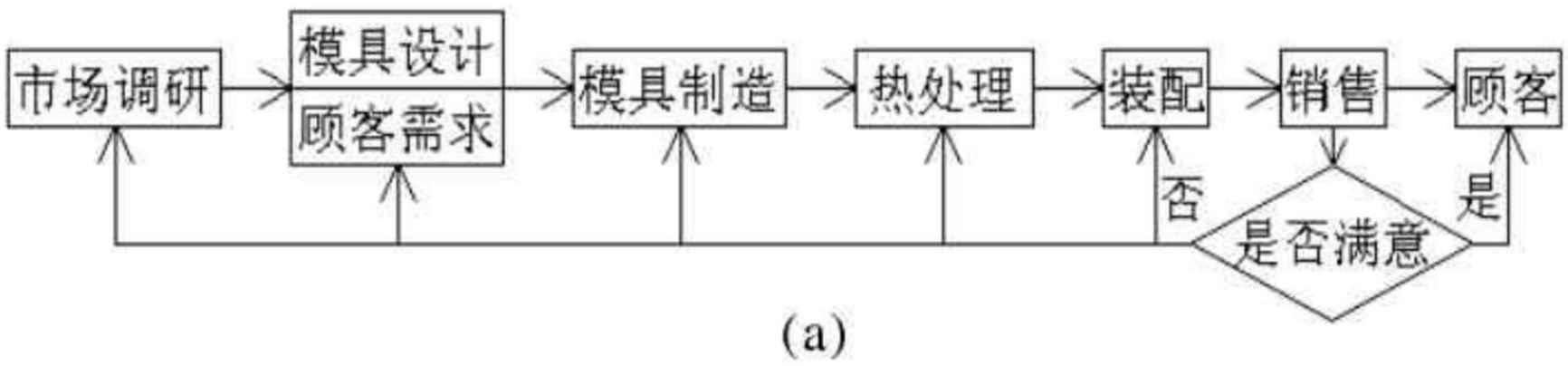
模具的热处理与模具设计，制造和装配同样重要。因为它对模具的制造装配和使用寿命又及其重要的影响。模具设计与制造发展十分迅速，但是热处理发展却严重滞后它们。随着模具工业的发展，热处理必须保证模具有良好的制造装配和磨损耐热性能。不切实际的热处理将导致模具材料过硬或过软，同时影响模具装配性能。传统的热处理工艺是按照设计师提出的方法和特性制作出来的。这样会使模具设计师和热处理工艺师意见产生分歧，而模具设计师却不能充分地了解热处理工艺和材料的性能，相反热处理工艺师却很少了解模具的使用环境和设计思路。这些分歧将在很大程度上影响模具的发展。因此，如果把热处理工艺设计放在设计阶段之前，则缩短开发周期，减少花费和保证质量等目标将会被考虑，而且从串行到并行的发展模式也将会实现。

并行工程是以计算机集成系统作为载体，在开始以后，每个阶段和因素都被看作如制造、热处理、性能等等，以避免出现错误。并行模式已经摒除了串行模式的缺陷，由此带来了一场对串行模式的革命。

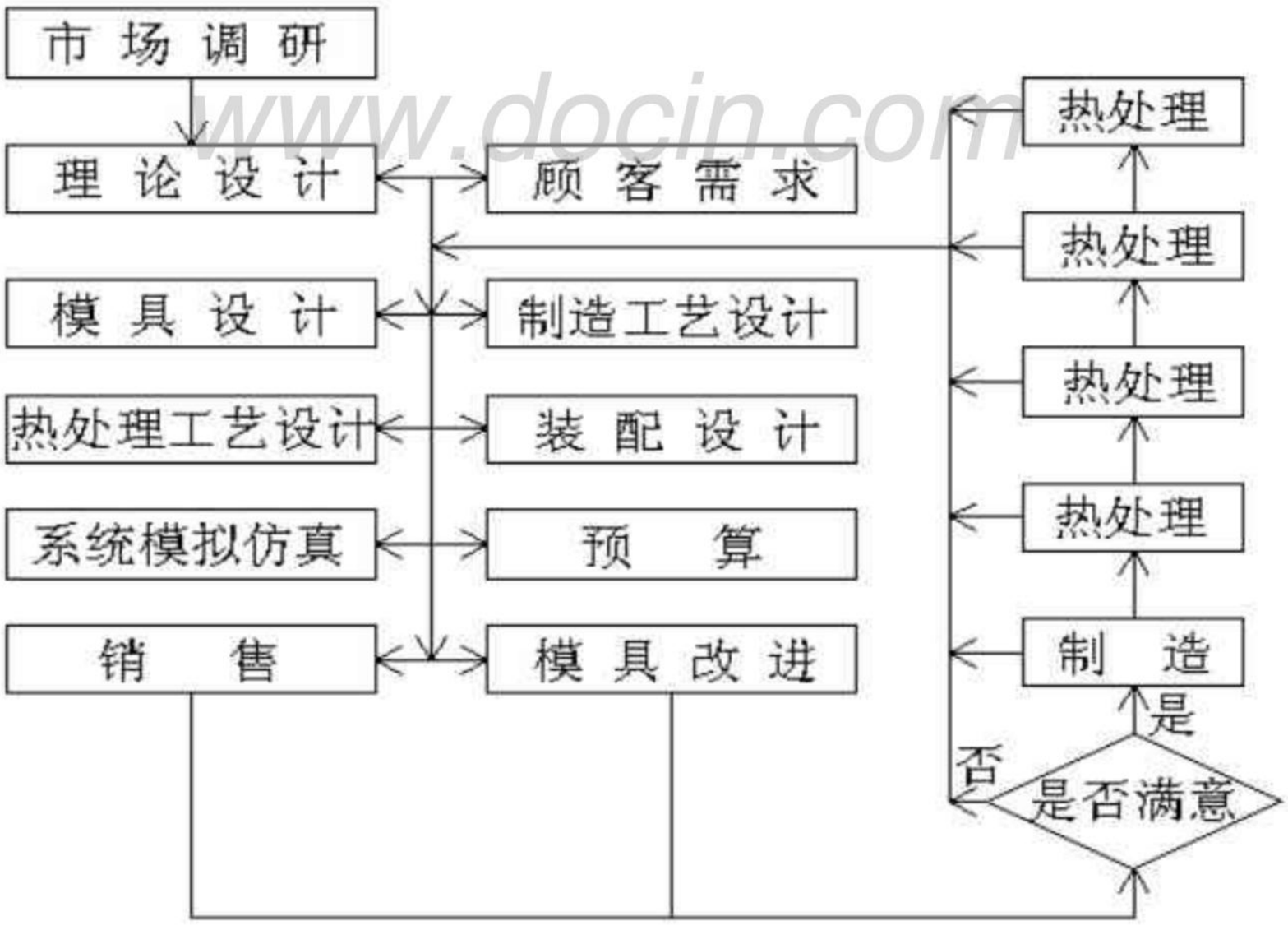
在当前的工作中，热处理被集成到了模具开发的并行环境中，同时也正在进行这种系统性和深入性的研究。

1. 热处理下的并行环境

并行模式与串行模式存在根本的不同（见图 1）。对于串行模式，设计者大多考虑的是模具的结构与功能，但很难考虑相关的工艺，以致前者的错误很容易蔓延到后面。与此同时，设计本门很少与装配，预算会计和销售部门沟通。这些问题当然会影响模具的开发进度和市场前景。然而在并行模式中，不但以上部门关系联系密切，所有参加模具开发的部门都与买家有密切的交流。这有助于协调各部门消除矛盾，提高工作效率，同时降低成本。



(a)



(b)

(a)串行模式　　（b）并行模式

图 1.基于摸具开发的串行工程与并行工程系统框架示意图

并行环境下的热处理工艺不是在方案和工件确定以后，而是在模具设计的时候制定出来的。这样的话，将有利于优化热处理工艺，充分利用材料。

2.模具热处理 CAD/CAE 一体化

从图 2 中可以看出，热处理工艺的设计与模拟是一体化模式的核心。在信息输入产品模块中后，经热处理工艺过程产生的热处理 CAD 和热处理 CAE 模块将对于零件图，热处理以后模拟温度场的微观结构分析和可能出现的缺陷（例如过热，烧伤）自动划分网络，如果优化是根据立体视觉技术的结果重新出现，则这项热处理工艺已经被审核。而且工具与夹具的 CAD 和 CAE 也集成于这种系统中

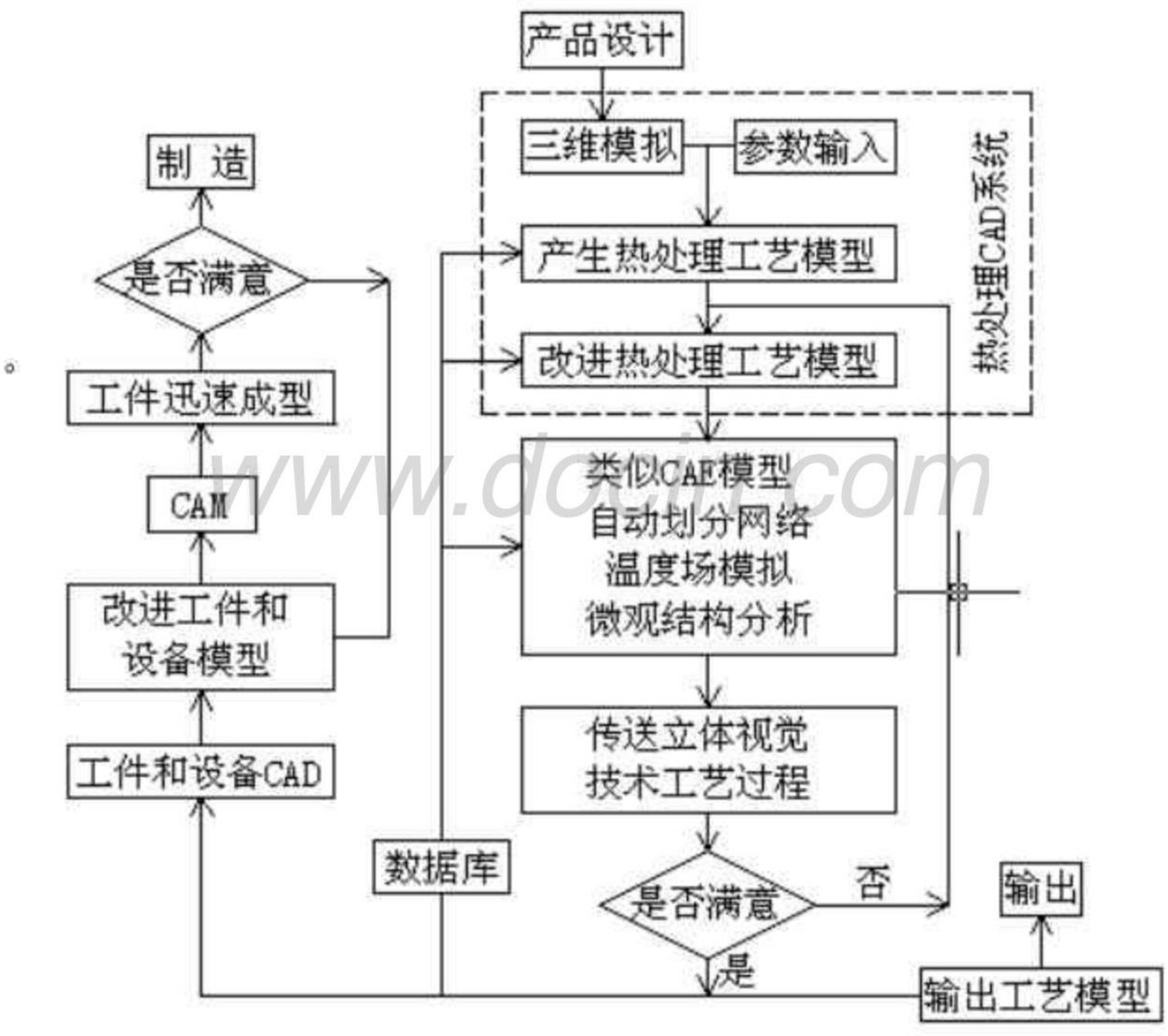


图 2.并行工程热处理 CAD/CAE 一体化系统框架示意图

以并行工程为基础的集成模式可以与其它类似模式共享信息。这样使热处理工艺得到优化，并确保改工艺准确。

2.1 采用三维模型和立体视觉技术的热处理

在形成模具的基础上，材料，结构和尺寸的问题能通过热处理三维模型尽快发现出来。在热处理过程中，模具加热条件和相变条件是切合实际的，因为通过计算相变热力、相变动力、相应力、热应力、传热速度、流体动力等已经取得重要突破。例如，能进行局部复杂表面和不对称模具的三维热传导模型计算，和能进行微观结构转变的 MARC 软件模型。计算机能够在任何时间提交温度，微观结构和应力的信息，并通过连接温度场微观结构领域和力场来显示三维形式的全部改变过程。如果再加上这种特性，则各部分性能都能通过计算机预见。

2.2 热处理工艺设计

由于对强度和硬度，表面粗糙度和模具热处理变形的特殊要求，淬火介质的种类、淬火温度、回火温度和时间等参数特性必须经过适当的选择，以及是否使用表面淬火或化学热处理，这种特性必须准确的制定下来。自从计算机技术在最近几十年迅速的发展，难以进行大型计算已经成为过去。通过模拟和仔细考虑热处理特性，热处理后的成本和所须时间，这些都并不难优化热处理工艺。

2.3 热处理数据库

热处理数据库在图 3 中描述。数据库是制定热处理工艺的基础。一般来说，热处理数据库分为材料数据库和工艺数据库。通过材料和工艺来预测特性已成为一种必然的趋势。尽管很难建立一个特性数据库，但通过一系列的测试来建立数据库是必要的。材料数据库包括材料牌号、化学成分、性能和国内外同级别目录表。工艺数据库包括热处理标准、种类、保温时间和冷却温度。基于数据库，热处理工艺可以通过推理规则创造出来

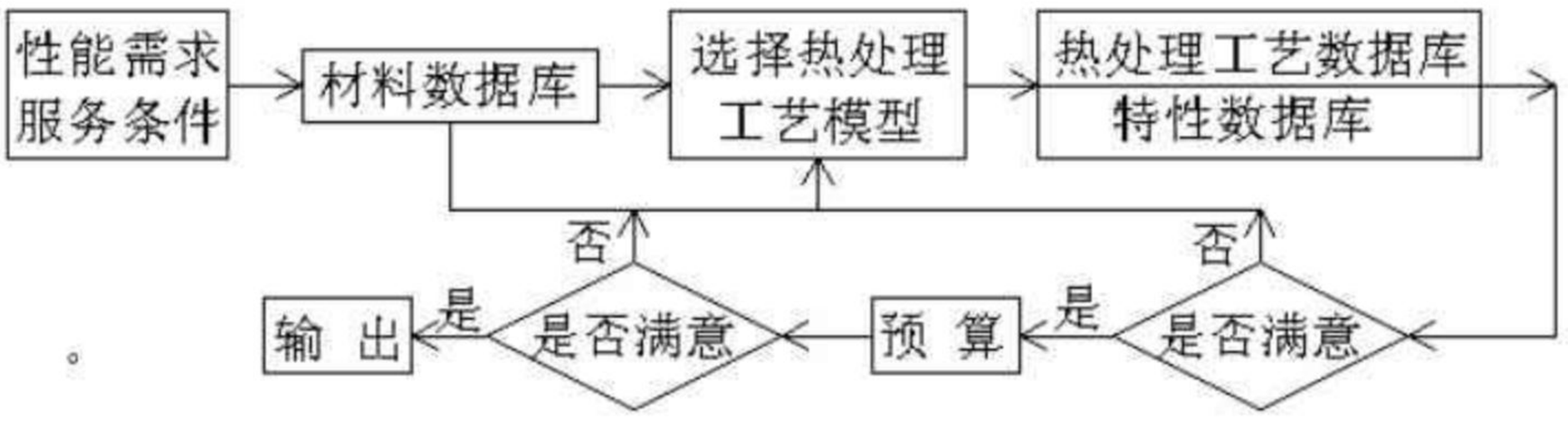


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图 3.热处理数据库

2.4 热处理工具和设备

在热处理工艺确定以后，工具及设备 CAD/CAE 系统传送设计和制造的数值信息来控制装置。通过快速模具成型，可靠的工具和夹具都能被确定。整个程序通过网络传送，不存在任何人为干扰。

3. 关键技术

3.1 温度，微观结构，应力和特性的联系

热处理程序是一个温度，微观结构和应力互相作用的程序。三方面都能影响材料特性（见图 4）。在加热和冷却期间，当微观结构转变时热应力和相变迟早会出现。微观结构温度相变和温度－微观结构－应力特性相互影响。对相互作用的四个因素的调查已经取得很大的发展，但普通的数学模型还没有建立。许多模型能很好的满足测试结果，但不能投入到实践当中。大部分模型的难点是用分析的方法处理的，同时数值方法也运用了，导致存在不准确的计算

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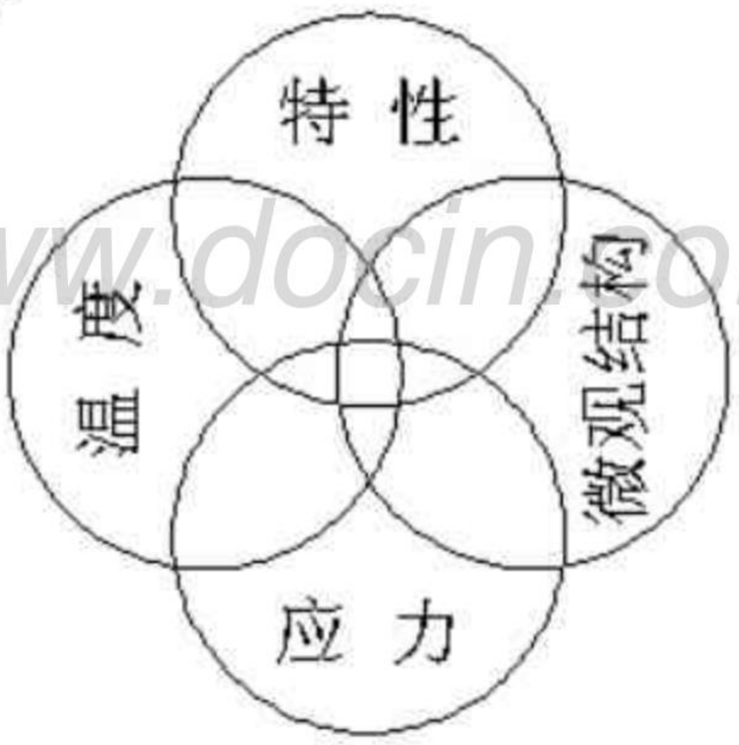

图 4.热处理工艺图解

即使如此，把经验方法与定性分析相比较，通过计算机来进行热处理模拟取得了很大的进展。

3.2 模型的建立和融合

在模具的开发过程中，涉及到设计、制造、热处理、装配、维修等。它们应该有自己的数据库和模型。它们通过事物的内在联系建立模型，互

相串联起来，尽管建立和运用动态推理机制，但其目的在于完成优化设计。产品模型和其它模型的联系已被建立。如果细小组织模型发生改变，则产品模型也将改变。事实上，它属于数据库与模具之间的联系。当热处理模型集成到系统以后，它已不再是一个孤立的单位，而是一个部分，同时在系统中接近其它模型。在搜查后，热处理数据库的计算和推理能力，热处理程序都被几何模型，模具制造模型和预算所限制，这是通行的。如果这种限制不服从，系统会发出解释性的警告。

所用设计的细小组织都是通过互连网连接的。

3.3 各部分之间的管理和协调

复杂的模具需要其中各项目组之间密切合作。因为考虑到模具的开发，各部分都存在缺点，它必须得到管理和协调。首先，各项目组应该确定其本身的控制条件和资源要求，同时了解不同环境下的工作程序，以避免发生冲突。其次，要提出开发计划和建立监控机制。如果开发受到限制则可逐步排除。

敏捷管理和协调有助于交流信息，提高效率和减少材料。同时这有利于激发人的创造力，消除阻碍和制定出最好的方法。

4. 总结

⑴热处理 CAD/CAE 技术已被集成到模具并行设计中去，同时热处理已被制成图表，这有利于提高效率，较易发现问题并解决问题。

⑵模型的开发已在同一个平台运行。在这个平台中，当热处理工艺制定出来后，设计人员可获得相关信息和转让部分信息到其它设计部门。

⑶制定出正确的开发计划并按时调整可以极大缩短开发周期和降低成本。

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李雄，张鸿冰，阮雪榆，罗中华，张艳.模具热处理及其导向平行设计[J]. 钢铁研究学报英文版，2006，13（1）:40-43，74