

铸造浇注系统的计算机模拟分析^{**}昆明理工大学 郭跃华^{**} 舒信福 唐瑞春 朱延东

摘 要 设计了 4 种浇注系统,并且采用 Z-CAST 软件对铸件进行了充型和凝固的模拟分析,通过对模拟结果的分析来对浇注系统进行了优化和改进。发现加 3 块冷铁,并改变冷铁加入的位置,冒口的补缩效果很好。从而得到了一种最优的设计方案。

关键词: Z-CAST 浇注系统 模拟分析

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由于曲轴铸件的形状复杂,尺寸大小不一,材料又不尽相同,因而对于同样的铸件,工艺设计人员的计算结果就不一定一致。铸造模拟软件出现后,人们使用计算机来模拟铸造的过程,改进工艺设计^[1,2]。

1 计算机模拟分析

采用韩国 Z-CAST 软件对 3100QB 柴油机曲轴的 4 种浇注系统进行模拟分析,并且分别模拟了其充型及凝固情况,根据模拟结果分析这 4 种浇注系统对铸件充型和凝固过程的影响,其中第 2~4 种浇注系统的设计都是在前一种设计方案的基础上进行了改进,目的是尽量减少铸件的缩孔、缩松、气孔和夹渣等缺陷,提高铸件的质量,降低生产成本。

1.1 几何模型的建立

采用的模型由 Pro/engineer2001 进行三维造型,然后转化为 STL 格式导入 Z-CAST,网格的剖分为正六面体网格,网格的大小为 5 mm,网格数目为:172 × 127 × 45 = 982 980。由 Z-CAST 自带的网格剖分模块剖分。

1.2 制作材料、成型工艺条件

所采用的几何模型为传统工艺生产的 3100QB 柴油机曲轴,材料为 QT700,浇注工艺参数:浇注时间为 20~25 s,浇注温度为 1 350,铸件采用立式浇注,每箱两件。

1.3 浇注系统的设计

设计了 4 种浇注系统方案,后 3 种都是在前 1 种的基础上进行改进,最后得到了 1 种较好的浇注方案。

试验方案 1:采用半开放式浇注系统,加顶冒口^[3]。浇注系统设计如图 1 所示。由于该工艺采用了半封闭的浇注系统,分析模拟结果发现(见图 2),沿下部内浇道注入型腔的铁水上升到铸件 1/3 高度时,铁水便从上部的横浇道经冒口进入型腔;这样上半部分和下半部分的铁水相互交汇时会造成局部的高温区,导致该区域最后凝固而产生缩孔缩松;并使铁水中的渣极易在这个区域富集造成夹渣缺陷。同时,上下两部分铁水的交汇将

产生紊流而卷入气体,增加气孔的形成几率,并容易造成这个区域的铁水氧化。显然,这种方案是不可取的。

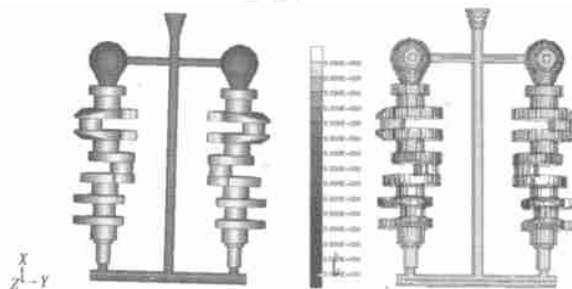


图 1 试验方案 1 图 2 试验方案 1 充型过程模拟结果

方案 2:对试验方案 1 进行了部分改进,如图 3 所示,去掉上面和冒口相连的横浇道,加大直浇道、下部横浇道和内浇道的尺寸,这样既可满足充型时间的要求,而且也不会形成方案 1 充型时的两部分铁水交汇的现象,可在很大程度上减少夹渣和气孔的形成。但是由于热节的影响,在凝固的过程中会出现上部铁水先凝固下部铁水后凝固的现象,冒口将起不到补缩作用。在凝固过程很有可能在曲轴的中部(如图 4 中还没有凝固的部分)出现缩孔和缩松现象,从中可以看出铸件在该工艺条件下不是顺序凝固,而是在铸件中部还没凝固时冒口和铸件之间的补缩通道就已经凝固,中部的热节在凝固过程中由于得不到补缩很容易造成缩孔或缩松缺陷。所以方案 2 的模拟结果也不是很理想。

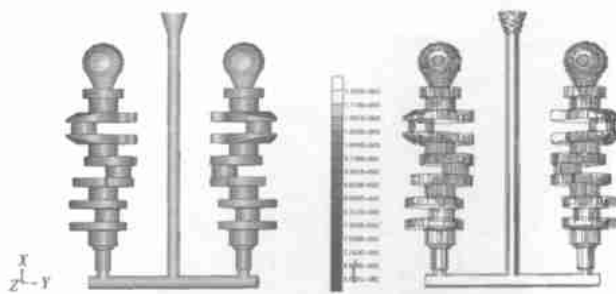


图 3 试验方案 2 图 4 试验方案 2 的凝固过程模拟结果
试验方案 3:加冷铁。根据方案 2 的模拟结果,在适当的位置加放冷铁如图 5 所示。在图 5 所示位置加

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放了3块冷铁,虽然冒口和铸件之间的补缩通道凝固的比较晚,可在一定程度上减轻缩孔和缩松缺陷出现的可能,但由于冷铁放置的位置不对,效果并不是十分理想,还是没有实现顺序凝固。铸件中下部的热节部分在整个铸件中仍然处于最后凝固的区域(见图6),由于补缩通道已提前凝固,冒口仍然无法对曲轴中下部进行有效补缩。因此,该区域依然可能出现缩孔和缩松缺陷。

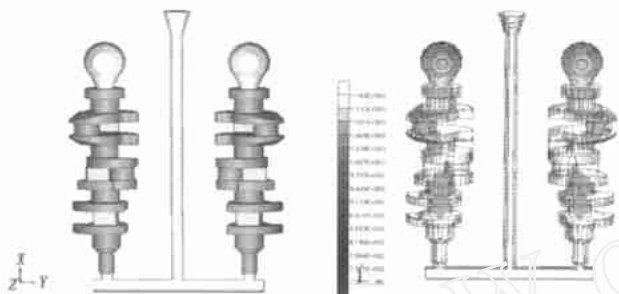


图5 试验方案3 图6 试验方案3的凝固过程模拟结果
试验方案4:加3块冷铁,改变冷铁加放的位置(图7),如图8所示可以看到铸件为顺序凝固,最后凝固的部位为冒口,冒口可以起到很好的补缩效果。效果比较理想。所以最后采用试验方案4。

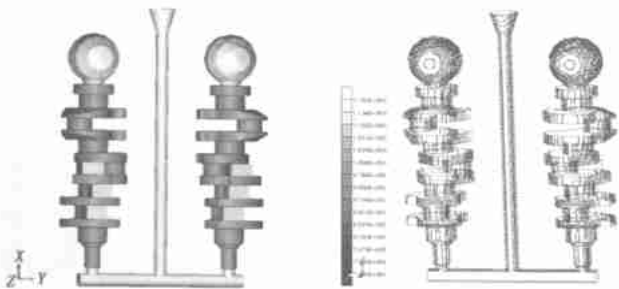


图7 试验方案4 图8 试验方案4凝固过程模拟结果

2 结果分析及讨论

2.1 结果分析

3100QB 柴油机曲轴浇注系统的设计是基于 Z-CAST 凝固模拟软件,从软件应用过程中可以看出,该软件在球墨铸铁凝固过程中对铸件模数、铸型刚度等重要影响因素还没有进行有针对性的设计,在某些场合,很可能与现代均衡凝固理论还存在一些冲突。例如,均衡凝固理论中冒口不能设计在有热节的地方,但是本试验冒口设置正是在热节处,经过模拟发现只要是铸造工艺及冒口的尺寸设计合理就可以把缩孔和缩松出现的位置集中到冒口处,而不会出现均衡凝固理论所设想的出现在冒口颈和铸件之间的现象。

在软件的应用中可以发现,该软件的设计思想基本是根据顺序凝固的原理进行编程的。本课题开始采用了阶梯式浇注,希望凝固过程中处于铸件上部冒口中的高温铁水能对铸件起到很好的补缩效果^[4]。但经过模拟发现这种方案有很大的不合理性,在浇注过程中上面横浇

道过早地流入铁水,一方面对铸型的冲刷作用比较大,另一方面还可能卷入气体造成气孔或夹渣等缺陷^[5]。所以试验方案2取消了阶梯式浇注工艺,但这又造成上部铁水温度低,下部铁水温度高,铸件容易产生缩孔和缩松缺陷。通过模拟结果可以看出铸件很有可能会在铸件中部出现缩孔和缩松缺陷。根据这个模拟的结果,试验方案3在铸件的中下部加了3块冷铁,但由于冷铁放置的位置不对,效果还不是很理想。所以试验方案4同样是放置3块冷铁,但改变了冷铁放置的位置。根据模拟结果可以明显看出,该工艺使铸件基本实现了由下至上的顺序凝固,冒口成为最后的凝固区域,补缩效果得到很大改观,铸件中基本不会有缩孔和缩松出现。

2.2 讨论

(1) 浇注系统的设计

浇注系统的设计对铸件质量有很大影响,铸件尺寸为 860 mm × 217 mm × 226 mm,由于铸件较高,因此要避免浇注过程中金属液对铸型的冲刷,金属液自由下落冲刷过大、容易产生飞溅、氧化和卷入空气等不良现象,另外要特别注意避免热节部位产生缩孔和缩松缺陷,所以采用了底注式浇注工艺,这可以在一定程度上避免砂眼、气孔和夹渣等缺陷。加放冷铁可以让铸件实现顺序凝固,冒口可以起到很好的补缩效果。

(2) 对 Z-CAST 软件的初步认识

铸造模拟软件 Z-CAST 可以分析铸件充型和凝固过程中可能出现的缺陷,设计人员可以在分析结果的基础上进行优化和改进。但任何东西都有其局限性,它只是一个辅助工具,不可能完全替代浇注系统设计人员的经验和知识,浇注系统设计得越合理,对其改进起来就越容易,甚至不需要改进。

3 结语

Z-CAST 软件可以模拟充型和凝固的过程,软件的理论依据是顺序凝固理论,它只能定性分析缩孔和缩松出现的位置,不能预测其大小,对 Z-CAST 软件的模拟结果进行分析的依据也是顺序凝固理论,能够根据结果推测在某个位置可能出现缩孔或缩松,而不能确定其肯定出现,不能定量分析其大小。Z-CAST 软件可以在一定程度上起到提高工作效率,缩短浇注系统的设计周期,降低成本的作用。

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Abstract Although the research on the mold used for semi-solid alloy rheological forming is a main part of the semi-solid alloy rheological forming, attractive attention hasn't yet been paid. According to the analysis on the running principle of mold and the working conditions of ferrous metal in semi-solid rheological forming, it is found that the main failures of mold include thermal fatigue, melt erosion and deformation. It is also pointed out that the key properties of mold material include fatigue strength at high temperature, the oxidation resistance and the lower linear expansion rate. With analysis of both advantages and disadvantages of conventional mold materials, it is concluded that there aren't any mold materials suitable for ferrous metal in semi-solid rheological forming at home and abroad now. It is an effective approach to improve the mold service life using composites and surface treatment methods.

Key Words: Semi-solid Alloy, Rheological Forming, Mold Material, Ferrous Metal

Simulation Analysis of Gating System Guo Yuehua Shu Xinfu Tang Ruichun Zhu Yandong (Kunming University of Science and Technology, Kunming, China) 2004(2)36~37

Abstract Simulation analysis of mold filling and solidification of the casting was conducted in 4 varieties of gating system with Z-cast software. The optimization and improvement of gating system were done based on analysis of simulation results to obtain the optimized design sketch. It is found that the use of three chills and proper adjustment of the setting position can improve effectively poured quality.

Key Words: Z-cast, Gating System, Simulation Analysis

Numerical Simulation of Temperature Field on Multi-steps Samples for Al Alloy Xiong Xiaoqing Wu Zhichao Ye Shengping (Huazhong University of Science and Technology, Wuhan, China) 2004(2)38~40

Abstract The application of ANSYS general software to numerical simulation for temperature field during casting solidification was approached. The numerical simulation on multi-steps sample and actually pouring for Al alloy were respectively conducted. It was showed that numerical simulation results obtained with ANSYS software were well in agreement with actually poured results through establishing suitable mathematical model and setting rational boundary conditions.

Key Words: ANSYS, Numerical Simulation, Al Alloy

Design Idea and Method for Nonferrous Casting Technology in Ancient China Liu Keming (Huazhong University of Science and Technology, Wuhan, China) 2004(2)40~43

Abstract Numerous masterpieces in metallurgical technology have been deposited in civilization history of China. For thousands of years, the ancient caster not only created countless very great works but also noted many profound technological ideas and design methods. The generalization of engineering technological language in ancient foundry industry, the standardization of denomination and relevant terminologies in product design, standardization and method of chemical composition determination in cast alloy, and the principle

and method of parametrization design as well as the idea and method of state in equilibrium and harmony were discussed in ancient foundry of China.

Key Words: Nonferrous Alloy Casting, Design Idea, Design Method

Cu Segregation and Flow Behavior of Al-Si-Cu Alloy under Local Pressurization Wan Li (Huazhong University of Science and Technology, Wuhan, China) Eji Kato Horoyuki Nomura (Nagoya University, Nagoya, Japan) 2004(2)44~46

Abstract Cu segregation of two varieties of Al-Si-Cu alloy with different solidification behaviors under partial pressurization conditions was researched. It was found that Cu segregation of the AC4B alloy with mushy solidification was susceptible to negative segregation located below pressurization bar and dependant on the time of initial pressurization, while the ADC12 alloy with unidirectional solidification only exhibited slightly negative segregation in annular position about 5 mm below pin tip and was not dependant on the time of initial pressurization. In contrast, it presented positive segregation. The Cu segregation was attributed to the local flow of the condensed liquid through interdendrite.

Key Words: Die Casting, Partial Pressurization, Al-Si-Cu Alloy, Negative Segregation, Positive Segregation, Interdendritic Liquid Flow

Favorable Opportunity and Challenges of Die Casting Market in China Song Caifei (Shanghai Precision Scientific Instrument Limit., Co., Shanghai, China) 2004(2)47~49

Abstract The present status and developing prospect of die casting market in China were surveyed. The total turnout of components in die casting is 0.624 million tons, in which Al alloy parts in 0.4156 million tons, and Zn alloy parts in 0.1982 million tons, and Mg alloy parts in 5000 tons and 5300 tons Cu alloy parts in 2002 year. Per year sold die casting machines is about 1800, in which 2% is large machine with above 10000 kN, 38% is middle machine with 3000~9000 kN and 60% is small machine with below 3000 kN. The total turnout values of die in home is up to 36 billions in 2002 year, in which about 10% is die casting die. The above 80% die casting enterprises consist of foreign invested enterprises and private enterprises as well as villages and towns enterprises and the very large die casting enterprise group appears.

Key Words: Die Casting Market, Components in Die Casting, Die Casting Equipment, Die Casting Die, Die Casting Alloy

Reclamation and Recycle of Silica Sol Mold Shell Molding Waste Zhao Hengyi (Ningbo University, Ningbo, China) Wang Jianming (Inner Mongolia Polytechnic University, Inner Mongolia, China) 2004(2)50~51

Abstract Silica sol mold shell waste was crushed, magnetic alloy