

学校编码: 10384  
学 号: 19920101152731

分类号 \_\_\_\_\_ 密级 \_\_\_\_\_  
UDC \_\_\_\_\_

厦 门 大 学

硕 士 学 位 论 文

卡套针阀的理论实验研究

Theoretical Analysis and Experiment Study of  
Ferrule Needle Valve

廖 仲 生

指导教师姓名: 胡国清 教授

专 业 名 称: 机械工程

论文提交日期: 2013 年 月

论文答辩日期: 2013 年 月

学位授予日期: 2013 年 月

答辩委员会主席: \_\_\_\_\_

评 阅 人: \_\_\_\_\_

2013 年 月

## 厦门大学学位论文原创性声明

本人呈交的学位论文是本人在导师指导下,独立完成的研究成果。本人在论文写作中参考其他个人或集体已经发表的研究成果,均在文中以适当方式明确标明,并符合法律规范和《厦门大学研究生学术活动规范(试行)》。

另外,该学位论文为( )课题(组)的研究成果,获得( )课题(组)经费或实验室的资助,在( )实验室完成。(请在以上括号内填写课题或课题组负责人或实验室名称,未有此项声明内容的,可以不作特别声明。)

声明人(签名):

年 月 日

错误! 未指定书签。

厦门大学博硕士学位论文摘要库

## 厦门大学学位论文著作权使用声明

本人同意厦门大学根据《中华人民共和国学位条例暂行实施办法》等规定保留和使用此学位论文，并向主管部门或其指定机构送交学位论文(包括纸质版和电子版)，允许学位论文进入厦门大学图书馆及其数据库被查阅、借阅。本人同意厦门大学将学位论文加入全国博士、硕士学位论文共建单位数据库进行检索，将学位论文的标题和摘要汇编出版，采用影印、缩印或者其它方式合理复制学位论文。

本学位论文属于：

(        )1.经厦门大学保密委员会审查核定的保密学位论文，于  
年    月    日解密，解密后适用上述授权。

(        )2.不保密，适用上述授权。

(请在以上相应括号内打“√”或填上相应内容。保密学位论文应是已经厦门大学保密委员会审定过的学位论文，未经厦门大学保密委员会审定的学位论文均为公开学位论文。此声明栏不填写的，默认为公开学位论文，均适用上述授权。)

声明人(签名)：

年    月    日

错误! 未指定书签。

厦门大学博硕士学位论文摘要库

## 摘要

针阀是现代工业领域重要的执行或调节元件之一，广泛应用于石油、化工、市政、电力等关系国计民生的重要领域。卡套针阀是针阀的一种，具有较高的流量调节精度、较好的流量调节线性度，由于采用了卡套式接头，卡套针阀还具有优秀的接头快速密封性能，具有广阔的市场前景和研究价值。本文主要工作如下：

(1) 在充分研究了卡套针阀工作原理的基础上，根据阀门设计手册、《MSS SP-99 仪表阀门》等技术标准，对卡套针阀进行了总体结构设计，用 Solidworks 建立了相应的三维模型；计算校核了阀体壁厚和阀杆强度，并运用有限元分析软件 Patran/Nastran 进行了有限元分析验证；分别研究、推导了金属和填料密封原理，并求解了阀盖、填料螺母的预紧力矩等关键参数。

(2) 在充分研究了双卡套管接头工作原理的基础上，结合工程实际明确了后卡套的设计要素；结合运用正交试验方法和 Patran/Nastran 有限元分析的手段，研究了后卡套的各个设计要素对其自身性能乃至管接头整体综合性能的影响；通过对有限元分析结果进行正交数据处理，得出了一个优化的后卡套设计方案、总结出了有效的后卡套设计方法。

(3) 设计了一款用软轴作为传动轴、连接灵活可靠、性能稳定的用于卡套针阀静压寿命试验的装置。包括总体设计、机械结构设计、电气控制方案设计、电气元件选型、电气控制柜钣金件设计；推导并求解了阀杆外螺纹与阀盖内螺纹之间的摩擦力，并据此对软轴进行选型；编译了阀门试验的运动控制程序。

(4) 根据国标《GBT26143-2010 液压管接头试验方法》，为新型双卡套管接头拟定了较完整的试验方案，通过试验，验证了新型双卡套管接头优异的综合性能，可以在恶劣的工作环境中保证可靠的密封；根据《API598-2004 阀门的检查和试验》、《GBT13927-2008 工业阀门压力试验》，为新型卡套针阀拟定了较完整的压力和寿命试验方案，通过试验，验证了新型卡套针阀优秀的性能。

**关键词：**卡套针阀 双卡套管接头 有限元分析 试验装置 性能验证试验

错误! 未指定书签。

厦门大学博硕士学位论文摘要库

## Abstract

The needle valve is an important executive component in modern industry, it's widely used in petroleum industry, chemical industry, municipal construction, electric system and some other important areas. Ferrule needle valve is one branch of needle valve which with higher flow regulation accuracy, better flow regulation linearity. As a result of using bite type tube fittings, the interfaces of ferrule needle valve can be fast sealed. The main contents of this thesis are as follows:

(1) Based on the full study of ferrule needle valve's working principle, the overall structural design is finished by strictly complying with some instructive technical standards. The 3D models are established by using Solidworks. The valve body thickness and valve stem strength are calculated and checked, the related finite element analysis are done to verify the results by using Patran/Nastran. Researches on the principle of metal and packing seal are done separately, some key parameters like the pre-tightening torque of bonnet and packing nut are solved.

(2) Based on the full study of bite type tube fittings' working principle and engineering practice, identification of back ferrule's design elements is done. Researches on the influence of each back ferrule's design elements to itself and tube fitting are done by combining orthogonal experiments and finite element analysis. By processing the result data of orthogonal experiments, an excellent back ferrule design is obtained, and the design methods of back ferrule is summed up.

(3) A service life testing device of the ferrule needle valve is developed, which using flexible shaft as transmission shaft, with flexible and reliable connection, show stable performance. Including overall design, mechanical design, electrical control system design, selection of electrical components, and electrical control cabinet sheet metal design. Research on the friction force between the stem male thread and bonnet cap thread are done, and accordingly the flexible shaft selection is finished. The motion control program is compiled.



错误! 未指定书签。

(4) Based on the related instructive technical standards, a complete testing program for the new bite type tube fitting is made, and accordingly the excellent sealing performance of it in harsh working environment is verified. Based on the related instructive technical standards, a complete testing program for the new branch of ferrule needle valve is made, the excellent performance of ferrule needle valve is verified by the results of testing experiments.

**Key Words:** Ferrule Needle Valve; Bite Type Tube Fitting; Finite Element Analysis; Experiment Device; Performance Verification Experiment

## 目 录

中文摘要 .....	I
英文摘要 .....	II
第一章 绪论 .....	1
1.1 课题的研究背景 .....	1
1.2 国内外的研究发展现状 .....	2
1.2.1 国内的研究发展现状 .....	2
1.2.2 国外的研究发展现状 .....	3
1.3 阀门技术的发展趋势 .....	3
1.4 有限元技术的应用和发展 .....	5
1.4.1 有限元法概述 .....	6
1.4.2 有限元分析的基本步骤 .....	6
1.4.3 有限元常用软件介绍 .....	7
1.5 课题来源和意义 .....	8
1.6 课题的主要研究内容 .....	8
第二章 卡套针阀的方案设计 .....	10
2.1 设计任务书 .....	10
2.2 阀体的设计与计算 .....	11
2.2.1 阀体的结构设计 .....	11
2.2.2 阀体壁厚及其计算 .....	11
2.2.3 阀体壁厚仿真分析 .....	13
2.3 阀杆与阀芯的结构设计计算 .....	14
2.3.1 阀杆与阀芯的结构设计 .....	14
2.3.2 阀杆最大轴向力计算 .....	14
2.3.3 阀杆强度仿真分析 .....	17
2.4 阀门其他部件的结构设计 .....	18
2.4.1 阀盖的结构设计 .....	18
2.4.2 阀门背密封的设计 .....	19
2.4.3 防尘帽的设计 .....	19
2.5 阀门零件明细 .....	20

<b>2.6 阀体-阀盖金属密封的分析计算</b> .....	<b>20</b>
2.6.1 螺纹副的受力情况.....	21
2.6.2 接触端面的受力情况.....	22
2.6.3 影响密封性能的因素.....	23
2.6.4 密封比压.....	25
2.6.5 密封预紧力矩的分析计算.....	25
<b>2.7 填料密封的分析计算</b> .....	<b>28</b>
2.7.1 密封填料的受力分析.....	28
2.7.2 应力的影响因素讨论.....	30
2.7.3 密封填料分析结论.....	33
2.7.4 卡套针阀密封填料预紧力计算.....	33
<b>2.8 本章小结</b> .....	<b>36</b>
<b>第三章 新型高性能卡套的研究</b> .....	<b>37</b>
<b>3.1 双卡套管接头的工作原理</b> .....	<b>37</b>
<b>3.2 双卡套管接头的总体结构设计</b> .....	<b>38</b>
<b>3.3 后卡套设计要素的正交试验设计</b> .....	<b>39</b>
3.3.1 正交试验设计的概念及原理.....	39
3.3.2 试验设计.....	39
<b>3.4 双卡套管接头的有限元分析</b> .....	<b>40</b>
3.4.1 有限元模型的建立.....	40
3.4.3 约束及边界条件.....	42
3.4.4 接触对的定义.....	42
3.4.5 提交分析.....	43
3.4.6 读取分析结果.....	43
<b>3.5 正交试验分析结果处理</b> .....	<b>45</b>
3.5.1 有限元分析结果.....	45
3.5.2 各要素平均响应分析.....	45
3.5.3 最优方案性能验证.....	48
<b>3.6 最终设计方案</b> .....	<b>51</b>
<b>3.7 本章小结</b> .....	<b>51</b>
<b>第四章 阀门静压寿命试验装置</b> .....	<b>52</b>
<b>4.1 阀门的寿命试验</b> .....	<b>52</b>
<b>4.2 总体方案规划</b> .....	<b>52</b>
<b>4.3 动力系统的选型</b> .....	<b>53</b>
4.3.1 驱动方式的选择.....	53
4.3.2 电机的选择.....	53

<b>4.4 传动机构设计</b> .....	<b>55</b>
4.4.1 软轴的选型 .....	56
4.4.2 软轴联轴器的设计 .....	58
4.4.3 电机支架的设计 .....	58
<b>4.5 控制系统设计</b> .....	<b>59</b>
4.5.1 控制器的选型 .....	59
4.5.2 电气控制方案布局 .....	60
4.5.2 控制柜设计 .....	61
<b>4.6 整机装配及控制程序</b> .....	<b>63</b>
<b>4.7 本章小结</b> .....	<b>64</b>
<b>第五章 验证试验</b> .....	<b>65</b>
<b>5.1 卡套的性能试验</b> .....	<b>65</b>
5.1.1 双卡套管接头的装配流程 .....	66
5.1.2 气密性试验 .....	66
5.1.3 耐压试验 .....	67
5.1.4 爆破试验 .....	67
5.1.5 试验结果 .....	68
5.1.6 结论 .....	69
<b>5.2 卡套针阀的整体综合性能试验</b> .....	<b>70</b>
5.2.1 壳体试验 .....	71
5.2.2 上密封试验 .....	72
5.2.3 低压密封试验 .....	73
5.2.4 高压密封试验 .....	74
5.2.5 静压寿命试验 .....	75
5.2.6 试验结论 .....	76
<b>5.3 本章小结</b> .....	<b>77</b>
<b>第六章 总结与展望</b> .....	<b>78</b>
6.1 总结 .....	78
6.2 展望 .....	79
<b>参考文献</b> .....	<b>80</b>
<b>硕士期间发表的学术论文及取得的成果</b> .....	<b>84</b>
<b>致谢</b> .....	<b>85</b>

错误! 未指定书签。

厦门大学博硕士学位论文摘要库

## Table of Contents

<b>Abstract In Chinese .....</b>	<b>I</b>
<b>Abstract In English.....</b>	<b>II</b>
<b>Chapter 1 Introduction.....</b>	<b>1</b>
<b>1.1 Background of Project .....</b>	<b>1</b>
<b>1.2 Research and Development Status of Valve industry .....</b>	<b>2</b>
1.2.1 Research and Development Status of Valve industry in China.....	2
1.2.1 Research and Development Status of Valve industry in Abroad .....	3
<b>1.3 The Development Trend of Valve Industry .....</b>	<b>3</b>
<b>1.4 Application and Development of Finite Element Analysis Technology .....</b>	<b>5</b>
1.4.1 Overview of Finite Element Method .....	6
1.4.2 Basic Steps of Finite Element Analysis .....	6
1.4.3 Introduction of Some Softwares .....	7
<b>1.5 Sources and Significance of This Project .....</b>	<b>8</b>
<b>1.6 Major Work of This Project .....</b>	<b>8</b>
<b>Chapter 2 Design of The Ferrule Needle Valve.....</b>	<b>10</b>
<b>2.1 Design Task Book.....</b>	<b>10</b>
<b>2.2 Design and Research of Valve Body.....</b>	<b>11</b>
2.2.1 Structural Design of Valve Body .....	11
2.2.2 Verification of The Valve Body Thickness .....	11
2.2.3 Finite Element Analysis of Valve Body Thickness.....	13
<b>2.3 Design and Research of Valve Stem and Spool .....</b>	<b>14</b>
2.3.1 Structural Design of Valve Stem and Spool.....	14
2.3.2 Research on Maximum Axial Force of Valve Stem.....	14
2.3.3 Finite Element Analysis of Valve Stem Strength .....	17
<b>2.4 Design of Other Parts of Ferrule Needle Valve.....</b>	<b>18</b>
2.4.1 Structural Design of Valve Bonnet.....	18
2.4.2 Design of Back Seal.....	19
2.4.3 Design of Dust Cap.....	19
<b>2.5 Valve Parts Details.....</b>	<b>20</b>

<b>2.6 Research and Calculation On The Valve Body-Bonnet Sealing Face</b> .....	<b>20</b>
2.6.1 Stress Condition of Screw Pairs .....	21
2.6.2 Stress Condition of End-faces .....	22
2.6.3 Factors Affecting The Sealing Performance .....	23
2.6.4 Sealing Pressure .....	25
2.6.5 Analysis and Calculation of The Pre-Tightening Torque .....	25
<b>2.7 Research and Calculation On The Sealing Packing</b> .....	<b>28</b>
2.7.1 Stress Condition of Sealing Packing .....	28
2.7.2 Factors Affecting The Stress of Sealing Packing .....	30
2.7.3 The Conclusion of Analysis On Sealing Packing .....	33
2.7.4 Calculation of The Pre-Tightening Torque of Sealing Packing .....	33
<b>2.8 Chapter Summary</b> .....	<b>36</b>
<b>Chapter 3 Research of High-Performance Ferrule</b> .....	<b>37</b>
<b>3.1 Working Principle of Double Bite Type Tube Fitting</b> .....	<b>37</b>
<b>3.2 Overall Structural Design of Double Bite Type Tube Fitting</b> .....	<b>38</b>
<b>3.3 The Orthogonal Experiment of Back Ferrule Design Elements</b> .....	<b>39</b>
3.3.1 The Concept and Principle of Orthogonal Experiment .....	39
3.3.2 Design of Orthogonal Experiment .....	39
<b>3.4 The Finite Element Analysis of Double Bite Type Tube Fitting</b> .....	<b>40</b>
3.4.1 Establishment of Finite Element Models .....	40
3.4.3 Constrain and boundary .....	42
3.4.4 Definition of Contact-Pairs .....	42
3.4.5 Submit Analysis .....	43
3.4.6 Read Results .....	43
<b>3.5 Result Processing of Orthogonal Experiment</b> .....	<b>45</b>
3.5.1 Result of Finite Element Analysis .....	45
3.5.2 Average Response Analysis of Each Design Element .....	45
3.5.3 Performance Verification of The Optimal Design .....	48
<b>3.6 The Final Design</b> .....	<b>51</b>
<b>3.7 Chapter Summary</b> .....	<b>51</b>
<b>Chapter 4 Service Life Testing Device of The Ferrule Needle Valve</b> .	<b>52</b>
<b>4.1 Service Life Testing Experiment of Valves</b> .....	<b>52</b>
<b>4.2 Overall Design</b> .....	<b>52</b>
<b>4.3 Selection of Power System</b> .....	<b>53</b>
4.3.1 Selection of Drive Mode .....	53
4.3.2 Selection of Motor .....	53
<b>4.4 Design of Transmission Mechanism</b> .....	<b>55</b>

4.4.1 Selection of Flexible Shaft .....	56
4.4.2 Design of Couplings .....	58
4.4.3 Design of Motor Bracket .....	58
<b>4.5 Design of Control System.....</b>	<b>59</b>
4.5.1 Selection of Controller .....	59
4.5.2 Layout of Electrical Control System.....	60
4.5.2 Design of The Control Cabinet .....	61
<b>4.6 The Assembled Machine and Control Program .....</b>	<b>63</b>
<b>4.7 Chapter Summary .....</b>	<b>64</b>
<b>Chapter 5 Verification Experiments .....</b>	<b>65</b>
<b>5.1 Performance-testing Experiments of Back Ferrule .....</b>	<b>65</b>
5.1.1 Assembly Procedure of Double Bite Type Tube Fittings.....	66
5.1.2 Air Tightness Experiment .....	66
5.1.3 Hydraulic Pressure Experiment .....	67
5.1.4 Hydraulic Explosion Experiment.....	67
5.1.5 Result of Experiments .....	68
5.1.6 Experiments Conclusion .....	69
<b>5.2 Performance-Testing Experiments of Ferrule Needle Valve .....</b>	<b>70</b>
5.2.1 Valve Body Experiment .....	71
5.2.2 Back Seal Experiment.....	72
5.2.3 Low Pressure Seal Experiment .....	73
5.2.4 High Pressure Seal Experiment .....	74
5.2.5 Service Life Testing Experiment.....	75
5.2.6 Results of Experiments .....	76
<b>5.3 Chapter Summary .....</b>	<b>77</b>
<b>Chapter 6 Summary and Prospect .....</b>	<b>78</b>
<b>6.1 Summary .....</b>	<b>78</b>
<b>6.2 Prospect .....</b>	<b>79</b>
<b>References .....</b>	<b>80</b>
<b>Papers and Patents.....</b>	<b>84</b>
<b>Acknowledgements .....</b>	<b>85</b>



Degree papers are in the "[Xiamen University Electronic Theses and Dissertations Database](#)". Full texts are available in the following ways:

1. If your library is a CALIS member libraries, please log on <http://etd.calis.edu.cn/> and submit requests online, or consult the interlibrary loan department in your library.
2. For users of non-CALIS member libraries, please mail to [etd@xmu.edu.cn](mailto:etd@xmu.edu.cn) for delivery details.

厦门大学博硕士论文摘要库