上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

减速器分析与设计

实验指导书

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减速器分析与设计实验

减速器是一种普遍通用的机械设备，其结构包括传统件设计(直齿轮、斜齿轮，锥齿轮，蜗杆等)，支撑件设计(轴、轴承等)，箱体设计及密封等，是培养学生首次独立完成设计任务的良好参照设备。由于学生是首次独立进行机械产品设计，缺乏产品相关设计与开发经验，因此一定程度上会存在各种各样的问题：对齿轮结构、加工过程、安装形式不熟悉；对轴的结构、加工过程、选材、热处理不熟悉；对箱体结构、铸造(焊接)过程不熟悉；对轴承型号选择、密封形式选择、联接件选择与安装没有经验，所以让学生亲自动手进行机械产品的实物拆装与分析很有必要。通过对减速器设备的拆装与分析，使学生进一步了解和掌握各零部件的结构意义、加工工艺、安装方法，尤其是运动件与运动件之间的安装要求、运动件与固定件之间的安装要求、轴承的拆装等。通过产品实物装配与分析实验，可以巩固与提升学生对课本专业知识的理解和掌握，为今后的学习与发展奠定坚实的基础。

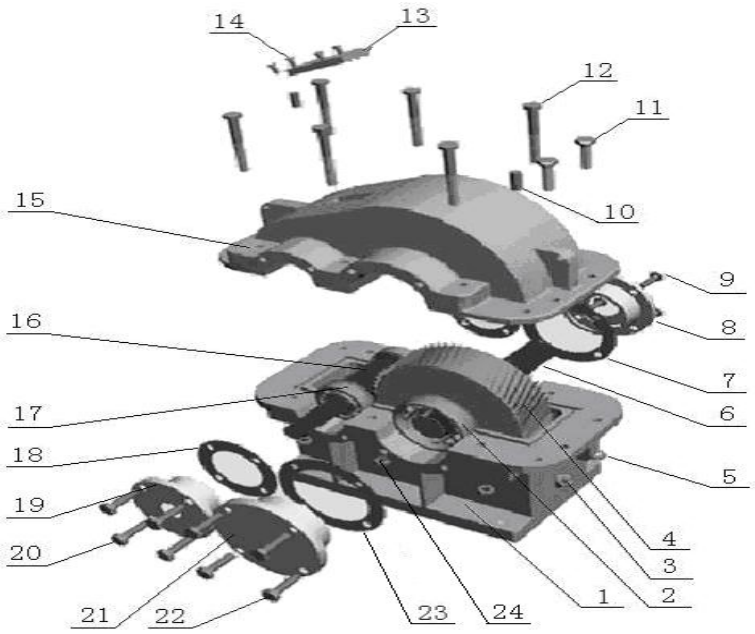


图 1 单级圆柱齿轮减速器

1.箱体　　2.轴承　　3.放油螺塞　　4.齿轮　　5.油标　　6.轴　　7.垫片　　8.端盖　　9.螺钉　　10.定位销　11、12.螺栓　　13.观察孔盖　14.螺钉　　15.箱盖　　16.齿轮轴　　17.轴承　18. 垫片　19.端盖　　20.螺钉　　21. 端盖　　22. 螺钉　23. 垫片　24.螺帽

一、实验目的

1、了解并熟悉减速器的功能、应用及整体结构，分析减速器中各个零件的作用及装配关系。

2、测定减速器的主要零部件的参数和精度。

3、测绘减速器主要零件的零件图并计算相关参数。

二、实验设备

1、单级直齿、斜齿圆柱齿轮减速器

2、双级直齿、斜齿圆柱齿轮减速器

3、圆锥－圆柱齿轮减速器

4、蜗杆减速器等实物及各种类型减速器模型

三、测量及拆装工具

游标卡尺、百分表、钢尺、扳手、十字、一字螺丝刀、拉马、压床等。

四、拆装步骤与实验内容

1、将减速器箱盖与箱体间的联接螺栓拆下，取出定位销，打开减速器箱盖。

2、分析传动方式、级数、输入、输出轴，并绘制传动零件图。

3、测量相关参数，并分析箱体结构形状，附件（观察孔、油标尺、油塞、吊耳等），轴上零件的定位固定方式及装配关系，润滑密封方式等。

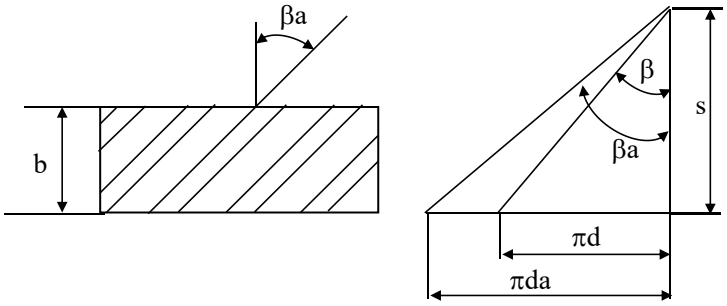
4、计算减速器的有关参数

传动比：　$i_{12}=\frac{Z_2}{Z_1}$　　$i_{34}=\frac{Z_4}{Z_3}$

法面模数：　$m_n=\frac{h}{2.25}$

端面模数：　$m_t=\frac{2a}{Z_1+Z_2}$

螺旋角：　$\beta=\arccos\frac{m_n(Z_1+Z_2)}{2a}$　　$\beta=\arccos\frac{m_n}{m_t}$



对于模数较小的齿轮螺旋角的测定可用滚压法：如图所示，在齿顶圆上用彩色粉笔轻涂后，在白纸上轻轻滚压，测出顶圆螺旋角βa，然后换算成分度圆螺旋角β　。

∵　$\mathrm{tg}\beta=\frac{\pi d}{s}$　　$\mathrm{tg}\beta_a=\frac{\pi d_a}{s}$

分度圆直径：　$d=\frac{m_n z}{\cos\beta}$　　顶圆直径：　$d_a=\frac{m_n(z+2)}{\cos\beta}$

∴　$\sin\beta=\frac{z\sin\beta_a}{z+2}$　　$\beta=\arcsin\frac{z\sin\beta_a}{z+2}$

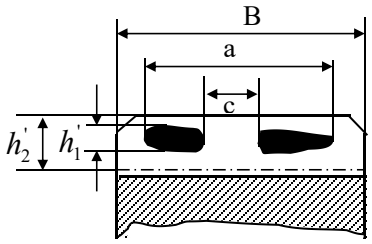
5、 分析减速器轴系部件的结构，绘制减速器高速轴轴系零件图，并将减速器装好复原。

6、 测定减速器传动精度

采用接触斑点作为对减速器传动精度的检验项目。仔细擦净每一个齿轮，将红铅油均匀地涂在主动轮的工作齿面上，用手转动输入轴，另一手轻握输出轴，使齿轮在一个微小的阻力下工作。转动后，观察从动轮轮齿齿面接触斑痕的分布情况，并沿齿宽、齿高方向测量接触斑痕的尺寸。按图 2 绘出接触斑点分布图。

齿宽接触%为 $\frac{a-c}{B}$ 100%

齿高接触%为 $\frac{h_1'}{h_2'}$ 100%



图—2

式中h_2'为工作高度，其值为$h_2' = 2\,m$n

7、 测定侧隙

在相啮合轮齿间，插入直径稍大于齿侧间隙的铅丝。转动主轴，铅丝随轮齿前进并受到挤压变形。齿侧间隙的 Cn 等于变形后铅丝厚度的两倍。

8、轴承轴向间隙的测定与调整

安装固定好百分表，用手推动轴至一端，然后再推动它至另一端。百分表上所指示的量即轴向间隙的大小。适当增减轴承端盖处调整垫片厚度进行调整，直至符合要求。对于嵌入式轴承盖用调整环或调整螺钉进行调整。

五、注意事项

1、实验前认真阅读实验指导书。

2、拆装过程中不准用锤子或其他工具打击任何零件。

3、拆装过程中同学之间要相互配合与关照，做到轻拿轻放，以防砸伤手脚。

减速器分析与设计实验报告

一、减速器类型_____

二、实验记录及实验计算结果

参　数	高　速　级	低　速　级
中心距 α_1、α_2		
小齿轮齿数 Z_1、Z_3		
大齿轮齿数 Z_2、Z_4		
小齿轮顶圆直径 d_{a1}、d_{a3}		
大齿轮顶圆直径 d_{a2}、d_{a4}		
小齿轮全齿高 h_1、h_3		
大齿轮全齿高 h_2、h_4		
小齿轮轮齿齿厚 s_1、s_3		
大齿轮轮齿齿厚 s_2、s_4		
小齿轮螺旋线方向		
大齿轮螺旋线方向		
总传动比 i		
分传动比 i_{12}、i_{34}		
法面模数 m_{n_1}、m_{n_3}		
端面模数 m_{t_1}、m_{t_3}		
压力角 α		
螺旋角 β_1、β_3		

注：减速器铭牌上的参数 h 是设备安装参考数据，不可用于相关参数计算！

三、测绘高速轴（输入轴）及其轴承（轴承画剖面图)的装配图，并标注相关尺寸、精度与公差等。

***四、侧隙计算(选作)**

侧隙 Cn ＝_____ mm

***五、接触精度(选作)**

沿齿宽接触 $\frac{a-c}{B}_x 100\%$＝_____

沿齿高接触 $\frac{h_1'}{h_2'}_x 100\%$ ＝_____

接触精度_____级 （精度等级确定参考机械设计手册）

六、思考题

1、轴上零件（如齿轮、轴承、联轴器等）是如何定位和固定的?

2、滚动轴承在安装时为什么要留出轴向间隙?　应如何调整?

3、减速器中哪些零件需要润滑?　如何选择润滑剂?

4、如何选择减速器主要零件的配合与精度?如齿轮、联轴器与轴的配合，滚动轴承与轴及箱体孔的配合。

七、心得与体会

上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

Reducer Structure Analysis and Design Experiment

Teacher： _____

Student Name： _____

Class： _____

Student ID： _____

Learning Center in School of Mechanical Engineering

Shanghai Jiao Tong University

Reducer Structure Analysis and Design Experiment

The reducer is a universal mechanical equipment. Its structure includes the traditional design (spur gear, helical gear, bevel gear, worm, etc.), support design (shaft, bearing, etc.), box design and sealing. Reducer is a good reference equipment for developing students fulfilling independent tasks for the first time.

As most of the students are the first to do independent mechanical design and are not familiar with gear structure, processing, installation forms, the axis of the structure, processing, selection, heat treatment, the structure of the box and the process of casting (welding), have little experience in the selection of the bearing type, the choice of the sealing form, the selection and installation of the coupling, Therefore, it is necessary to make the students to carry out the reducer experiment by themselves. Through the reducer disassembly and assembly experiment, students can make a visual understanding of the various parts of the reducer, and further understand and grasp the structure and meaning of the parts, processing technology, installation method, in particular, the

installation requirements of the moving parts and the moving parts, the installation requirements of the moving parts and the fixing parts, the bearing assembly and disassembly, etc., can play the role of half the effort through the disassembly and assembly experiment.

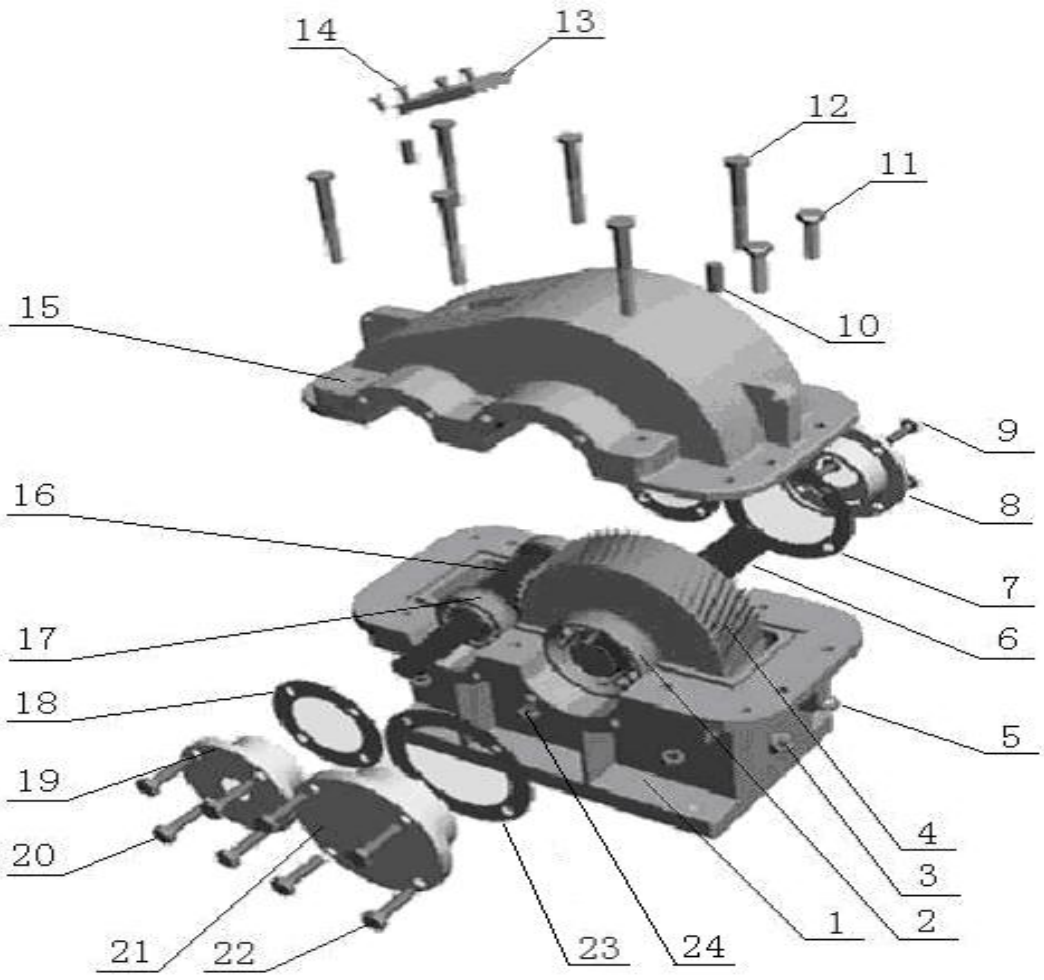


Fig.1. Single stage cylindrical gear reducer

1.Tank Body 2. bearing 3. drain plug 4.gear 5.oil gauge 6.axis 7. shim 8. end cover 9. screw 10. dowel 11、12. bolt 13.observation cover 14. screw 15. tank cover 16. gear shaft 17. bearing 18. shim 19. end cover 20. screw 21. end cover 22. screw 23. shim 24.nut

I、Experimental Objective

1、Get familiar with the structure of the reducer, analyze the role of every parts and. assembly relationship

2、Measure the main parameters and accuracy of reducer

II、Experimental Equipment

1、Single stage spur gear reducer, Helical cylindrical gear reducer

2、Double stage spur gear reducer, Helical cylindrical gear reducer

3、Bevel-Helical gear reducer

4、Worm reducer and other types of reducer model

III、Measuring and Assembling Tool

Vernier caliper、dial gage、steel rule、wrench、cross type and slot type screwdriver,etc.

IV、Disassembly Steps and Experimental Contents

1、Remove the connecting bolt between the tank cover and the tank body, remove the positioning pin, and open the gear box cover.

2、Analyze transmission mode, series, input, output shaft, and draw the transmission diagram.

3、Measurement related parameters and analyze the shape and structure of tank body, its accessory (observation hole, oil gauge, oil plug, lifting lug, etc.), positioning methods and assembly relations of shaft parts, lubrication and sealing method, etc.

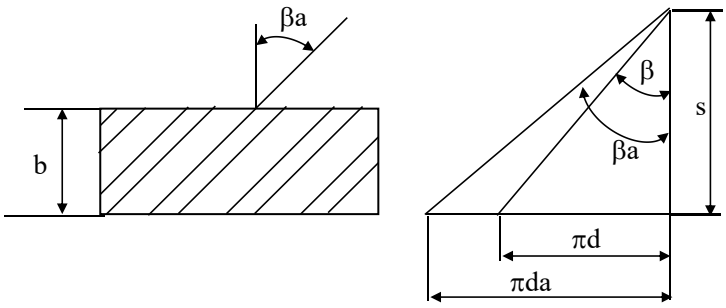
4、Calculate relevant parameters of the reducer

transmission ratio： $i_{12} = \frac{Z_2}{Z_1}$ $i_{34} = \frac{Z_4}{Z_3}$

normal module： $m_n = \frac{h}{2.25}$

transverse module： $m_t = \frac{2a}{Z_1 + Z_2}$

helical angle： $\beta = \arccos\frac{m_n(Z_1 + Z_2)}{2a}$ $\beta = \arccos\frac{m_n}{m_t}$



For the measurement of small modulus gear's spiral angle, we can use rolling process: as shown in the figure, after coating addendum circle with colored chalk, roll it on white paper, measure the top round helix angle βa and then convert it into helix angle β.

∵ $\text{tg}\,\beta = \frac{\pi d}{s}$ $\text{tg}\beta_a = \frac{\pi da}{s}$

reference diameter $d = \frac{m_n z}{\cos\beta}$ tip diameter $da = \frac{m_n(z+2)}{\cos\beta}$

∴ $\sin\beta = \frac{z\sin\beta_a}{z+2}$ $\beta = \arcsin\frac{z\sin\beta_a}{z+2}$

5. Analyze the structure of shaft components, draw shaft parts diagram

of reducer high speed shaft and install the reducer to its original state.

6. Determination of reducer transmission precision

The contact spot is used as the test item of the reducer transmission precision. Carefully wipe every gear, coat red oil evenly on the surface of the working tooth of driving wheel, use one hand to rotate the input shaft, and use the other hand to hold the output shaft, and let gear work in a small resistance. After rotation, observe the distribution of contact driven tooth blackspot, And measure contact spot size along the tooth width and tooth height. Draw the distribution of contact spots as Fig.2

Tooth wide contact% is $\frac{a-c}{B}$ 100%

tooth height contact% is $\frac{h_1'}{h_2'}$ 100%

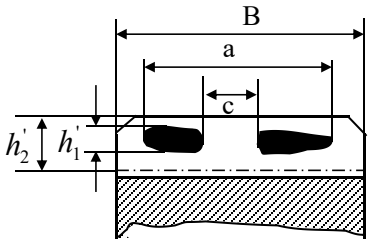


Fig.2

In the formula, h_2' is working height， $h_2' = 2\,m_n$

7、 The determination of clearance

In the meshing gear, insert a galvanized wire whose diameter is slightly larger than the tooth side clearance. Rotate principal axis, the wire will move forward with tooth and cause extrusion deformation. The tooth side clearance Cn is equal to two times the thickness of the deformed wire.

8、Measurement and adjustment of axial clearance of bearing.

Install and fix dial indicator，Push the shaft to the end with the hand, and then push it to the other end. The readings on the dial gauge is the axial clearance。Increase or decrease the sickness of adjusting shim at the bearing end cove until it meets the requirement. Use adjusting ring or adjusting screw for embedded bearing cap.

V、Caution

1、Read experimental guide book carefully before experiment.

2、Do not use a hammer or any other tool to combat any part during disassembly process.

3、During disassembly process, students should cooperate and take care with each other, do it gently to avoid any injury to hands and feet.

Reducer Structure Analysis and Design Test Report

I、Reducer type _____

II、Experimental records and experimental results

Parameters	High speed	Low speed
center distance α_1、α_2		
small gear teeth Z_1、Z_3		
gig gear teeth Z_2、Z_4		
tip diameter of small gear $d\alpha_1$、$d\alpha_3$		
tip diameter of big gear $d\alpha_2$、$d\alpha_4$		
whole depth of small gear h_1、h_3		
whole depth of big gear h_2、h_4		
tooth thickness of small gear s_1、s_3		
tooth thickness of big gear s_2、s_4		
direction of small gear helix		
direction of big gear helix		
total reduction ratio i		
Separated reduction ratio i_{12}、i_{34}		
normal module m_{n_1}、m_{n_3}		
transverse module m_{t_1}、m_{t_3}		
pressure angle α		
helix angle β_1、β_3		

Note: the parameter h on the reducer nameplate is equipment installation

reference data, and cannot be used for the calculation of relevant parameters!

III、Measure and draw the high speed shaft and its bearing parts (draw cross-section diagram) of the assembly drawing, and mark the relevant dimensions.

***IV、Lateral clearance calculation(optional)**

Lateral clearance C_n = _____ mm

***V、Contact accuracy (optional)**

contact along the tooth width $\frac{a-c}{B}_x 100\% =$_____

contact along the tooth depth $\frac{h_1'}{h_2'}_x 100\% =$_____

contact accuracy _____level （Refer to machine design manual for accuracy level determination）

VI、Questions to be considered

1、How to locate and fix the parts (such as gears, bearings, couplings, etc.) on the shaft?

2、When installing rolling bearing, why should the axial gap be set aside? And how to adjust?

3、Which parts of the reducer need to be lubricated? How to choose the lubricant?

4、How to select the match and precision of the reducer's main parts, such as the match of gear, coupling and shaft, the match of rolling bearing ,shaft and the hole of the tank body.

VII、Gains in depth of comprehension