

# 弧齿锥齿轮分流传动系统几何接触分析

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**摘 要:** 弧齿锥齿轮分流传动系统适用于复杂的功率分流场合。分析了其应用于船舶传动中不同工况下的功率流向, 以一种典型的工况为例, 提出了弧齿锥齿轮分流传动系统几何接触的分析方法。在弧齿锥齿轮副接触分析的基础上, 通过综合考虑系统存在边缘接触和安装错位误差, 系统各齿轮副的啮合情况, 设计出了系统的齿面印痕和传动误差图, 为优化系统的啮合性能和进一步分析系统各齿轮副的承载情况提供了理论依据。

**关 键 词:** 船用齿轮; 弧齿锥齿轮; 分流传动系统; 齿面印痕; 传动误差

中图分类号: U664.22; TH132.4 文献标识码: A

## 引 言

弧齿锥齿轮具有承载能力高, 传动平稳等特点, 用于转速较高或要求结构紧凑的场合, 在航空、汽车及舰船方面广泛应用。弧齿锥齿轮分流传动系统由采用功率分流形式布置的 4 个轴交角为直角的弧齿锥齿轮构成, 既综合了弧齿锥齿轮的各项优点, 又能实现功率交叉分流以及明显增大系统传递功率。图 1 为弧齿锥齿轮分流传动系统在一种船用交叉传动装置中的应用, 在实现功率交叉分流, 提高系统传递功率的同时, 又显著的减小了交叉传动装置的尺寸及重量, 具有良好的应用前景。

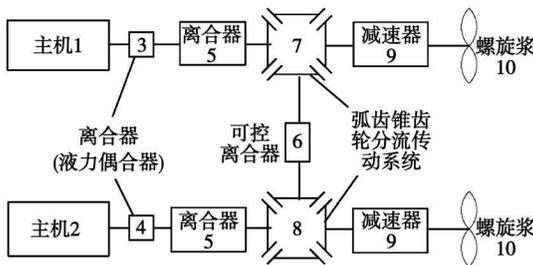


图 1 弧齿锥齿轮分流传动系统的应用

sis)的基础上<sup>[2-3]</sup>, 提出弧齿锥齿轮分流传动系统 TCA 方法, 对弧齿锥齿轮分流传动系统的齿面印痕和传动误差进行了设计, 从而为检验弧齿锥齿轮分流传动系统的几何接触性能提供了理论依据, 并为进一步的功率分流计算提供了理论基础。

## 1 系统建模

基于如下条件, 由图 1 建立弧齿锥齿轮分流传动系统的模型如图 2 所示。(1)弧齿锥齿轮刚性支撑;(2)弧齿锥齿轮副的传动比  $i=1$ ;(3)弧齿锥齿轮副轴交角为直角。

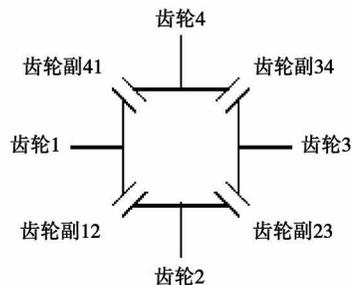


图 2 弧齿锥齿轮分流传动系统模型

如图 1 所示, 系统包括 3 种典型的工况, 工况 1: 主机 1 和 2 同开, 离合器 3 和 4 关闭, 6 打开, 系统 7 和 8 之间不存在功率流动, 两系统内部功率分流情况相同, 即齿轮 1 处输入功率, 齿轮 3 处输出功率, 齿轮 2 和 4 处无功率流动; 工况 2: 主机 1 开, 2 关闭, 离合器 3 打开, 4 和 6 关闭, 系统 8 处有功率流向系统 7, 即系统 8 中齿轮 1 处输入功率, 齿轮 2 和 3 处输出功率, 齿轮 4 处无功率流动; 工况 3: 在工况 2 中主机和离合器开关情况下, 系统 7 中齿轮 2 处输入功率, 齿轮 3 处输出功率, 齿轮 1 和 4 处无功率流动。分析各工况下系统的功率分流情况如图 3 所示。

本研究在弧齿锥齿轮 TCA (Tooth Contact Analy-

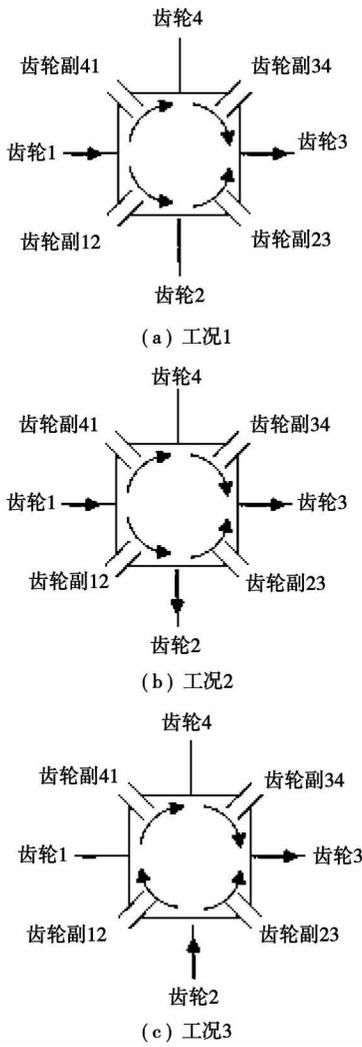


图 3 各工况下系统功率流向图

## 2 系统几何接触分析

表 1 轮坯参数

|                           | 齿轮 1 和 3 | 齿轮 2 和 4 |
|---------------------------|----------|----------|
| 齿数 $Z$                    | 34       | 34       |
| 压力角 $\alpha / (^\circ)$   | 20       | 20       |
| 螺旋角 $\beta / (^\circ)$    | 25       | 25       |
| 螺旋方向                      | 右        | 左        |
| 分锥角 $\gamma / (^\circ)$   | 45       | 45       |
| 面锥角 $\gamma_f / (^\circ)$ | 48.006   | 48.006   |
| 根锥角 $\gamma_r / (^\circ)$ | 41.993   | 41.993   |
| 外锥距 $A_w / \text{mm}$     | 199.546  | 199.546  |
| 齿宽 $B_w / \text{mm}$      | 60       | 60       |
| 齿顶高 $h_a / \text{mm}$     | 7.055    | 7.055    |
| 齿根高 $h_f / \text{mm}$     | 8.615    | 8.615    |
| 齿顶隙 $C / \text{mm}$       | 1.56     | 1.56     |

弧齿锥齿轮分流传动系统几何接触分析以弧齿锥齿轮副 TCA (考虑边缘接触) 为基础, 根据不同工况下的功率流向, 综合考虑系统各齿轮副的边缘接触和安装错位误差, 系统啮合情况 (各齿轮在各齿轮副中的主动与被动, 工作面为凹面或凸面, 转角对应关系, 传动误差的补偿, 各齿轮副初始齿间间距) 对啮合性能的影响, 计算并设计出系统的齿面印痕和传动误差曲线, 为系统的功率分流计算提供了基础条件。本研究以工况 2 为例, 进行设计计算, 系统中各齿轮的轮坯参数如表 1 所示。

### 2.1 各齿轮副几何接触分析

认为系统功率输入端齿轮 1 在齿轮副 12 中的工作面为凹面, 由图 3(b) 判断各齿轮在各齿轮副的啮合情况如表 2 所示。

齿轮副 12 的 TCA 基于基本方程组:

$$\begin{cases} \vec{r}_h^{(1)}(\theta_p, \phi_p, \varphi_1) = \vec{r}_h^{(2)}(\theta_g, \phi_g, \varphi_2) \\ \vec{n}_h^{(1)}(\theta_p, \phi_p, \varphi_1) = \vec{n}_h^{(2)}(\theta_g, \phi_g, \varphi_2) \end{cases} \quad (1)$$

式中: 1, 2—齿轮 1 和 2;  $h$ —各矢量均表示在固定坐标系  $S_h$  (固连于系统箱体中);  $\theta_p, \phi_p$ —齿轮 1 齿面 (凹面) 的曲面坐标;  $\theta_g, \phi_g$ —齿轮 2 齿面 (凸面) 的曲面坐标;  $\varphi_1, \varphi_2$ —齿轮 1 和 2 在啮合中的转角。

表 2 各齿轮副啮合情况

|      | 齿轮副 12   | 齿轮副 23   | 齿轮副 34   | 齿轮副 41   |
|------|----------|----------|----------|----------|
| 齿轮 1 | 主动<br>凹面 | —        | —        | 主动<br>凹面 |
| 齿轮 2 | 被动<br>凸面 | 主动<br>凹面 | —        | —        |
| 齿轮 3 | —        | 被动<br>凸面 | 被动<br>凸面 | —        |
| 齿轮 4 | —        | —        | 主动<br>凹面 | 被动<br>凸面 |

以功率输入端齿轮 1 的转角  $\varphi_1$  为输入量, 求解方程组 (1), 进行边缘接触计算, 再求出齿轮副 12 的齿面印痕, 结合式 (2) 计算得到传动误差值:

$$\Delta\varphi_{12} = (\varphi_2 - \varphi_2^{(0)}) - \frac{Z_1}{Z_2}(\varphi_1 - \varphi_1^{(0)}) \quad (2)$$

式中:  $\varphi_1^{(0)}, \varphi_2^{(0)}$ —齿轮副 12 中齿轮 1 和齿轮 2 的初始位置;  $Z_1, Z_2$ —齿轮 1 和齿轮 2 的齿数。齿轮副 23 的 TCA 基于基本方程组:

$$\begin{cases} \vec{r}_h^{(1)}(\theta'_p, \phi'_p, \varphi'_3) = \vec{r}_h^{(2)}(\theta'_g, \phi'_g, \varphi'_2) \\ \vec{n}_h^{(1)}(\theta'_p, \phi'_p, \varphi'_3) = \vec{n}_h^{(2)}(\theta'_g, \phi'_g, \varphi'_2) \end{cases} \quad (3)$$

式中: 2, 3—齿轮 2 和 3;  $\theta'_p, \phi'_p$ —齿轮 3 齿面 (凸面)

的曲面坐标;  $\theta'_g, \phi'_g$ —齿轮 2 齿面(凹面)的曲面坐标;  $\varphi'_2, \varphi'_3$ —齿轮 2 和 3 在啮合中的转角, 其它符号意义如式(1)所示。

方程组(3)的输入量为齿轮副 23 中的主动轮(齿轮 2)的转角  $\varphi'_2$ 。需要注意的是,  $\varphi'_2$  的值由齿轮副 12 的 TCA 中  $\varphi_2$  的值考虑齿轮副 12 和 23 如下的啮合相位关系后求得。齿轮 2 在齿轮副 12 和 23 中转角相差  $\pi$ , 其啮合周期为  $T=2\pi/Z_2$ ,  $Z_2$  为齿轮 2 的齿数。当齿轮 2 齿数为偶数时, 对应的齿轮副 12 和 23 啮合相位一致, 在啮合周期中啮合位置一致; 即偶数齿时, 轮齿转角差对相应的两个齿轮副的啮合位置没有影响, 这时  $\varphi'_2 = \varphi_2$ ; 当齿轮 2 齿数为奇数时, 对应的齿轮副 12 和 23 的啮合相位相差半个啮合周期; 即奇数齿时, 轮齿转角差使两个齿轮副的啮合位置相差半个啮合周期等效的接触位置个数, 这时  $\varphi'_2 = \varphi_2 + T/2$ 。由此得到  $\varphi'_2$  的值, 同理计算得到齿轮副 23 的齿面印痕, 结合式(4)得到传动误差值:

$$\Delta\varphi_{23} = (\varphi'_2 - \varphi_2^{(0')}) - \frac{Z_3}{Z_2}(\varphi'_3 - \varphi_3^{(0')}) \quad (4)$$

式中:  $\varphi_2^{(0')}, \varphi_3^{(0')}$ —齿轮副 23 中齿轮 2 和 3 的初始位置;  $Z_2, Z_3$ —齿轮 2 和齿轮 3 的齿数, 其它符号意义如式(3)所示。

齿轮副 41 和 34 的 TCA 与齿轮副 12 和 23 的 TCA 类似, 齿轮副 41 的 TCA 方程组中的输入量即主动轮(齿轮 1)的转角为齿轮副 12 中齿轮 1 的转角  $\varphi_1$  的值考虑齿轮副 12 和 41 的啮合相位关系后求得, 齿轮副 34 的 TCA 方程组中的输入量即主动轮(齿轮 4)的转角由齿轮副 41 的 TCA 求出的齿轮 4 的转角考虑齿轮副 41 和 34 的啮合相位关系后求得, 根据以上分析进行计算, 即可得到齿轮副 41 和 34 的齿面印痕和传动误差值。

### 2.2 各齿轮副传动误差的补偿

由图 2 及表 2 可知, 齿轮 2 和 4 在构成的相邻齿轮副(齿轮副 12 和 23, 齿轮副 41 和 34)中工作面不同, 即齿轮 2 在齿轮副 12 和 23 中工作面分别为凸面和凹面, 齿轮 4 在齿轮副 34 和 41 中工作面分别为凹面和凸面, 则齿轮在相邻两个齿轮副中工作面的参考点不同, 这时各齿轮副的传动误差是基于不同工作面参考点求得。参考点是指瞬时传动比等于理论值(即两齿轮的齿数比)的点, 亦即齿轮齿面上的接触斑点中心。统一各齿轮副的传动误差以齿轮 2 和 4 的凸面做工作面的参考点为基准, 需要对以齿轮 2 和 4 凹面做工作面的参考点为基准求得的

传动误差进行补偿。

在无安装误差时, 求得以齿轮 2 和 4 凸面做工作面的参考点为基准时传动误差最大值  $E_p^1$ , 以齿轮 2 和 4 凹面做工作面的参考点为基准时传动误差最大值  $E_p^2$ :

$$E_p^1 = \max(\Delta\varphi_{12}, \Delta\varphi_{41})$$

$$E_p^2 = \max(\Delta\varphi_{23}, \Delta\varphi_{34})$$

式中:  $\Delta\varphi_{12}, \Delta\varphi_{23}, \Delta\varphi_{34}$  和  $\Delta\varphi_{41}$ —由上述各齿轮副几何接触分析求得的齿轮副 12, 23, 34 和 41 的几何传动误差。

则实际情况下以齿轮 2 和 4 凸面做工作面的参考点为基准的几何传动误差补偿:

$$\Delta\varphi'_{23, 34} = \Delta\varphi_{23, 34} + (E_p^1 - E_p^2) \quad (5)$$

式中:  $\Delta\varphi_{23, 34}$ —实际情况下以齿轮 2 和 4 凹面做工作面的参考点为基准求得的齿轮副 23 和 34 的传动误差;  $\Delta\varphi'_{23, 34}$ —补偿后以齿轮 2 和 4 凸面做工作面的参考点为基准求得的齿轮副 23 和 34 的传动误差。

### 2.3 各齿轮副初始齿间间距对系统几何接触的影响

由式(2)和式(4)可知, 由于系统各齿轮副中主动轮和被动轮的初始位置不同以及安装错位误差的影响, 引起了各齿轮副初始齿间间距不同, 求得各齿轮副的传动误差极值不同, 传动误差曲线产生了不同的纵向幅值错位。综合考虑各齿轮副初始齿间间距, 对系统的传动误差值进行优化。

根据各齿轮副传动误差值得到系统传动误差最大值  $E = \max(\Delta\varphi_{12}, \Delta\varphi'_{23}, \Delta\varphi'_{34}, \Delta\varphi_{41})$ 。

优化各齿轮副的传动误差值为:

$$\Delta\varphi'_{12} = \Delta\varphi_{12} - E$$

$$\Delta\varphi''_{23} = \Delta\varphi'_{23} - E$$

$$\Delta\varphi''_{34} = \Delta\varphi'_{34} - E$$

$$\Delta\varphi'_{41} = \Delta\varphi_{41} - E$$

式中:  $\Delta\varphi_{12}, \Delta\varphi'_{23}, \Delta\varphi'_{34}, \Delta\varphi_{41}$ —齿轮副 12, 23, 34, 41 经上述补偿后的传动误差值;  $\Delta\varphi'_{12}, \Delta\varphi''_{23}, \Delta\varphi''_{34}, \Delta\varphi'_{41}$ —优化后系统的传动误差值。

## 3 算 例

对此弧齿锥齿轮分流传动系统进行几何接触分析, 考虑该系统中齿轮 1 产生安装误差, 在齿轮副 12 中的轴交角误差为  $+1'$ , 在齿轮副 41 中的轴交角误差为  $-1'$ , 进行系统 TCA(考虑边缘接触)。

图 4 的系统齿面印痕包括齿轮副 12, 23, 34, 41

的齿面印痕(图(a), (b), (c), (d))。由图4可知, 齿轮副12和齿轮副41中齿轮2和齿轮4的齿面印痕由于 $+1'$ 和 $-1'$ 轴交角误差的影响, 分别向轮齿齿根的小端和齿顶的大端移动。

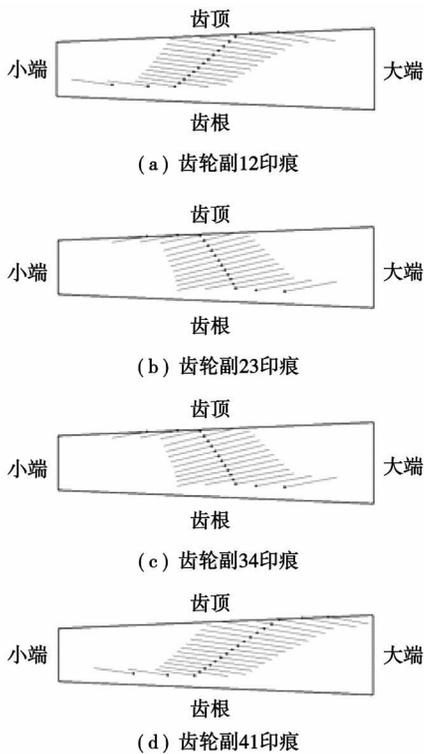


图4 系统齿面印痕

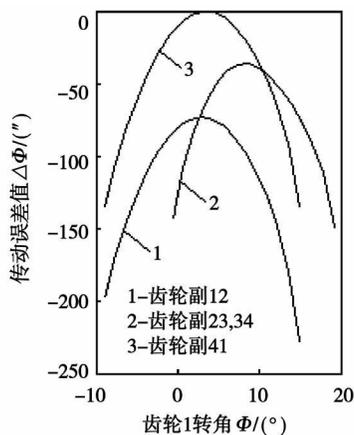


图5 系统传动误差图

图5的系统传动误差图由齿轮副12, 23, 34, 41

的传动误差组成。横坐标为系统功率输入端齿轮1的转角, 纵坐标为齿轮1转角对应的各齿轮副传动误差值, 对各齿轮副的传动误差进行了补偿, 考虑了存在上述安装错位误差时各齿轮副的初始齿间间距并进行了优化。由图5可知, 齿轮副23和34的初始齿间间距相等且啮合情况相同, 传动误差曲线重合, 齿轮副12传动误差曲线的相对纵向幅值错位最大, 齿轮副23和34的次之, 齿轮副41的最小为零。

## 4 结论

弧齿锥齿轮分流传动系统能够在复杂的功率分流场合实现双路功率的交叉分流, 应用前景广阔。本研究通过建立弧齿锥齿轮分流传动系统的模型, 分析其不同工况下的功率流向, 以及各齿轮副的啮合情况, 以弧齿锥齿轮TCA为基础, 综合考虑了系统存在边缘接触, 各齿轮副的啮合相位关系, 几何传动误差的补偿, 初始齿间间距对系统几何接触的影响, 以及系统存在安装误差的情况, 提出了对系统进行几何接触分析的方法。通过对弧齿锥齿轮分流传动系统TCA, 得到安装误差影响下系统的齿面印痕和传动误差图, 发现具有安装误差的齿轮副的齿面印痕发生了移动, 并且系统的几何传动误差曲线产生了纵向赋值错位。该方法为系统功率分流情况的计算提供了理论基础, 对设计、分析以及控制不同工况下弧齿锥齿轮分流传动系统的传动性能具有一定的理论指导意义。

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Li<sub>4</sub>SiO<sub>4</sub> 回收 CO<sub>2</sub> 的实验研究 = **Experimental Study of CO<sub>2</sub> Recovery by Using Li<sub>4</sub>SiO<sub>4</sub>** [ 刊, 汉 ] / LU Guo-qiang, YANG Shu-wen, MA Wen-hui, et al (College of Metallurgy and Energy Source, Kunming University of Science and Technology, Kunming, China, Post Code: 650093) // Journal of Engineering for Thermal Energy & Power. — 2009, 24(5). — 644 ~ 647

The CO<sub>2</sub> resource-oriented utilization is of major significance for realizing energy savings and harmful gas emissions reduction. On the basis of a thermodynamic analysis of Li<sub>4</sub>SiO<sub>4</sub> adsorbing CO<sub>2</sub> conducted by using HSC 5.1 thermodynamics database, the authors have analyzed and studied the performance of Li<sub>4</sub>SiO<sub>4</sub> adsorbing CO<sub>2</sub> by employing a self-developed thermal scale. They have also observed and evaluated respectively the material-phase composition after absorption of CO<sub>2</sub> by Li<sub>4</sub>SiO<sub>4</sub> at various temperatures and the microscopic surface morphological change characteristics before and after the absorption. It has been found from an analysis and test results that the material is most active in reactions for absorbing carbon dioxide at a temperature ranging from 600 °C to 720 °C and the maximal absorption quantity can reach about 29.16% (by weight). After absorption of CO<sub>2</sub>, the material begins to release CO<sub>2</sub> at 750 °C and then is regenerated to Li<sub>4</sub>SiO<sub>4</sub>. The volume percentage content of CO<sub>2</sub> has a notable influence on the absorption velocity and quantity of carbon dioxide by Li<sub>4</sub>SiO<sub>4</sub>. In an identical atmosphere, the gas flow rate has no conspicuous effect on the absorption velocity and quantity. **Key words:** lithium silicate, absorption, carbon dioxide

O<sub>2</sub>/CO<sub>2</sub> 气氛下痕量元素迁移特性试验研究 = **Experimental Study of Trace Element Migration Characteristics in an O<sub>2</sub>/CO<sub>2</sub> Atmosphere** [ 刊, 汉 ] / LU Jun-ying, CHEN Xiao-ping, DUAN Lun-bo, et al (College of Energy Source and Environment, Southeast University, Nanjing, China, Post Code: 210096) // Journal of Engineering for Thermal Energy & Power. — 2009, 24(5). — 648 ~ 651

On a tubular boiler, conducted was a combustion test of Xuzhou-originated bituminous coal and determined were the ash slag remnants from combustion by using an inductively coupled plasma-mass spectrometer (ICP-MS). The migration characteristics of trace elements were studied under various temperatures and combustion atmospheres (including air and O<sub>2</sub>/CO<sub>2</sub> atmosphere). The research results show that during the coal combustion process, such trace elements as Cr, Mn, Ni, Zn, Cd and Pb become enriched in the ash slag, and the As volatilization rate is over 70%. With an increase of temperature, the contents of the majority of trace elements in the ash slag will decrease. However, the contents of Mn, Ni and Cr in the ash slag are relatively stable. In an O<sub>2</sub>/CO<sub>2</sub> atmosphere, the changing tendency of various elements with temperature was not affected. In the O<sub>2</sub>/CO<sub>2</sub> atmosphere, as a whole, the contents of various trace elements in the ash slag are greater than those in air atmosphere. With an increase of temperature, the above-mentioned contents in the O<sub>2</sub>/CO<sub>2</sub> atmosphere are more and more close to those in the air atmosphere, indicating that the influence of the combustion atmosphere on the migration of trace elements is weakened with an increase of temperature. **Key words:** O<sub>2</sub>/CO<sub>2</sub> combustion, trace element, migration characteristics, tubular boiler

弧齿锥齿轮分流传动系统几何接触分析 = **Geometrical Contact Analysis of the Flow-dividing Transmission System of an Arc-tooth Cone Gear** [ 刊, 汉 ] / GU Jian-gong, FANG Zong-de (College of Electromechanical Engineering, Northwest Polytechnic University, Xi'an, China, Post Code: 710072), YU Dong-yang (CSIC Harbin No. 703 Research Institute, Harbin, China, Post Code: 150036) // Journal of Engineering for Thermal Energy & Power. — 2009, 24(5). — 652 ~ 655

The flow-dividing transmission systems of an arc-tooth cone gear are applicable for complex power flow-dividing cases. The authors have analyzed the power flow direction under different operating conditions when the systems in question are applied in a marine transmission plant. With a typical operating condition serving as an example, proposed was a method for analyzing the geometrical contact of the above transmission system. On the basis of the contact analysis of an arc-tooth

cone gear tooth, with a comprehensive consideration of a marginal contact in the system and errors resulting from the installation mismatch and engagement of various gear pairs in the system, designed was a chart indicating the tooth surface contact footprint and transmission errors of the system, thus, providing a theoretical basis for optimizing the system gear-meshing performance and further analyzing the load-bearing condition of various gear pairs in the system. **Key words:** marine gear, arc-tooth cone gear, flow-dividing transmission system, tooth surface contact pattern, transmission error

温度对污水污泥流化床热解油成分影响的 GC-MS 分析 = **GC-MS Analysis of the Influence of Temperature on Pyrolyzed Oil Constituents in a Sewage Water and Sludge Fluidized Bed** [刊, 汉] / JIA Xiang-ru, JIN Bao-sheng, LI Rui (College of Energy Source and Environment, Southeast University, Nanjing, China, Post Code: 210096) // Journal of Engineering for Thermal Energy & Power. — 2009, 24(5). — 656 ~ 660

By adopting a gas-phase chromatogram/mass spectrum joint usage technology, analyzed was the pyrolyzed oil obtained from sewage water and sludge through a pyrolysis in a fluidized bed at different temperatures. Through an analysis by using the above-mentioned technology, more than 100 constituents were identified in the oil from sludge pyrolysis. By employing a peak area method, quantitatively analyzed were various constituents and qualitatively analyzed were 29 constituents with a peak area ratio being greater than 1% in the pyrolyzed oil. Benzene and its compounds, alkene, carboxylic acid, polycyclic aromatic hydrocarbons (PAHs), nitrogen-contained compounds, chlorides and esters are found in the pyrolyzed oil. At 400 °C, esters predominate in the pyrolyzed oil. At 600 °C, the alkene content attains its maximum value and the distribution of various constituents becomes more uniform than at 400 °C. **Key words:** sewage water and sludge, oil, GC-MS analysis, pyrolysis, fluidized bed

新型医疗垃圾焚烧炉热力计算及优化 = **Thermodynamic Calculation and Optimization of a New Type Medical Waste Incinerator** [刊, 汉] / XIE Rong, LU Ji-dong, LI Jie (National Key Laboratory on Coal Combustion, Huazhong University of Science and Technology, Wuhan, China, Post Code: 430034) // Journal of Engineering for Thermal Energy & Power. — 2009, 24(5). — 661 ~ 665

Thermodynamically analyzed was a novel gas-controlled type medical waste pyrolysis and gasification incinerator. In the light of specific features of medical wastes and by employing a material and energy balance theory, the authors have calculated and analyzed the whole furnace, No. 1 and No. 2 combustion chamber of the incinerator. Obtained was a law governing the influence of the total excess air coefficient and No. 1 combustion chamber excess air coefficient on the outlet temperatures of the incinerator and No. 1 combustion chamber. When the total excess air coefficient increases from 1.6 to 2.0, the outlet temperature of No. 1 combustion chamber will go up from 640 °C to 1150 °C and in the meantime, the outlet temperature of the incinerator will gradually drop from 1000 °C to 650 °C. When the total excess air coefficient is kept constant and the excess air coefficient of No. 1 combustion chamber changes from 0.36 to 0.5, the outlet temperature of No. 1 combustion chamber will increase from 700 °C to 1100 °C and that of No. 2 combustion chamber will be kept at 900 °C. A combustion test was performed on a practical medical waste incinerator, and the test results were in relatively good agreement with the calculated ones. **Key words:** incinerator, excess air coefficient, optimization, thermal calculation

风力发电机大风限速保护方法的研究 = **A Study of Wind Speed Limit-related Protection Methods for Wind Turbine Generators During a Gale** [刊, 汉] / FENG Guo-ying, BAO Dao-ri-na, LIU Zhi-zhang, et al (College of Energy Source and Power Engineering, Inner Mongolia Polytechnic University, Huhhot, China, Post Code: 010051) // Journal of Engineering for Thermal Energy & Power. — 2009, 24(5). — 666 ~ 669

The most difficult problem faced by a small-sized wind turbine generator is the assurance of reliability, i. e. speed limit-related protection problem when a gale takes place. From the standpoint of energy conservation, the authors have analyzed