高效液力偶合器的动态特性分析

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[摘要]本文分析了高效液力偶合器传动系统的动态特性,研究了三种基本负载形式下的传递函数,通过仿真结果分析,了解系统抗负载波动的能力。

1 前言

液力偶合器已经广泛应用于工业生产中。对于大惯性的设备,因起动困难,利用液力传动十分有利。若直接用电机起动,则起动时间长,起动电流大,配备的电机容量也要增大。采用液力偶合器时起动性能会得到很大改善。液力偶合器还有过载保护的作用(如在工程机械中,其负荷变化幅度很大,常出现过载,而使用液力偶合器对传动装置则能起到保护作用)。液力偶合器在某些情况下还可当作液力制动器使用。因为利用液体作为工作介质,液力偶合器也能减弱动力机的扭转振动和隔离载荷振动。

目前广泛应用的液力偶合器存在(3~5)% 的滑差,即效率为(95~97)%。对于超过 300 KW 的大功率负载一般就要增设冷却系统,不仅使结构复杂、增加成本,也降低了传动可靠性。一般液力偶合器均带有前、后辅室或其中之一来起限矩作用,

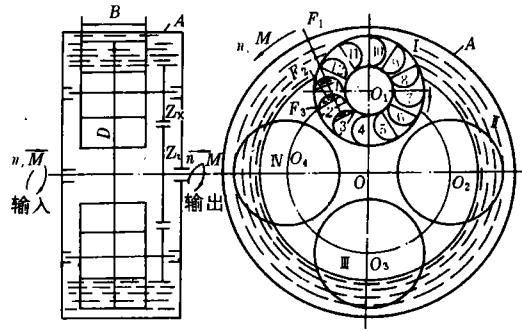其动态响应较慢。主要原因是液体由工作腔向辅室的流动需要一定的时间,从而导致限矩性能较差。一种新型的高效液力偶合器结构原理与普通液力偶合器不同,图1 为其工作原理示意图。

图 1 高效液力偶合器原理示意图

偶合器中的齿轮系统,即斗轮齿轮驱动太阳齿轮,斗轮上有叶片,象离心机械一样,叶片使液体的速度矩发生变化从而起到传递力矩的作用。将每个叶片的力矩相

叠加即为偶合器总的力矩。起动时内部液体在离心力的作用下形成油环，紧靠旋转外壳，斗轮与油环存在相对速度，液体推动斗轮转动，斗轮齿轮又绕太阳齿轮转动。因输入、输出转速不同步，液体被挖出旋转油环，并向偶合器中心的方向移动，这个过程离心力作功，这种作用直到输入、输出转速同步。滑差存在，斗轮齿轮就绕太阳齿轮转动，也说明阻力矩还小于输入力矩，随着输出转速的增加，斗轮齿轮绕太阳齿轮的转动速度减小，输入力矩也减小，直到阻力矩与输入力矩平衡斗轮绕太阳齿轮的转动消失，成为相对的"刚体"。额定工况力矩可以设计成任意大小。当过载时，输出转速减小，斗轮又绕太阳齿轮转动，输入力矩增加而与负载平衡，这时电机还是以额定转速运行，极限情况，如果输出轴被卡死不转，那么，电机也会受到保护，不至于超载。配上易熔塞，当工作液达到一定温度时，易熔塞熔化，油液喷出偶合器，使输入、输出脱开，电机空转。额定工况是靠液体的离心力矩闭锁，不存在滑差，理论效率为 100%，实际运行时，存在轴承的摩擦损失及风损，效率有所降低，在额定工况转速为 1450 r/min 时，存在 0.5% 左右的损失。液体与斗叶直接作用，不存在流动时间问题，其动态特性比一般液力偶合器要好。目前，英国、俄罗斯等国已投入应用，我国刚开始进行理论及试验研究。高效液力偶合器的扩大应用不仅节能，且使大功率、大惯性负载的起动问题得到根本性的解决。通过理论及试验研究还可发展成为调速型的，象液体粘性传动一样，调速范围可达到 100%。所以，研究其动态特性很有价值，通过动态分析可以了解其吸收负载波动的能力。

2　力矩平衡微分方程

在工作点附近斗轮力矩 M_D 可以简化为

$$Z \cdot M_D = M_0 + K_D \cdot \theta_D \tag{1}$$

式中：K_D —— 斗轮增益；
θ_D —— 斗轮工作角；
M_0 —— 启始力矩；
Z —— 斗轮数。

而动态时斗轮与负载平衡方程为

$$M_D = J_D \ddot{\theta}_D + B_D \dot{\theta}_D + T_D \tag{2}$$

$$T_T = J_T \ddot{\theta}_T + B_T \dot{\theta}_T + T_L \tag{3}$$

由图 1 知，太阳齿轮与斗轮齿轮啮合，则

$$T_T = Z \cdot j \cdot T_D \tag{4}$$

斗轮工作角为

$$\theta_D = j(\theta_B - \theta_T) \tag{5}$$

式中 J_T — 负载惯量；J_D — 斗轮惯量；B_T — 负载阻尼；B_D — 斗轮阻尼；T_T — 太阳齿轮力矩；T_D — 斗轮齿轮力矩；T_L — 负载力矩；j — 增速比；θ_B — 输入角；θ_T — 输出角。由式 (1)、(2)、(3)、(4) 得力矩平衡微分方程为

$$M_0 + K_D \theta_D = Z \cdot J_D \ddot{\theta}_D + Z \cdot B_D \dot{\theta}_D + (J_T \ddot{\theta}_T + B_T \dot{\theta}_D + T_L)/j \tag{6}$$

考虑三种负载型式

$$T_L = K_z \cdot \theta_T^n + M_L \tag{7}$$

式中：K_z — 负载系数；
M_L — 干扰力矩。

当 $n = 0$ 时为恒扭矩负载，$n = 1$ 为线性负载，$n = 2$ 为抛物线负载，液力传动基本为上述三种负载或其组合。

3　系统传递函数

当系统输入 θ_B 不变时，对式 (5)、(6)、(7) 取拉氏变换并整理得：

$n = 0$ 时

$$\frac{\theta_D(s)}{M_L(s)} = j/[(J_T/j - Z \cdot J_D)s^2 + (B_T/j^2 - Z \cdot B_D)s + K_D]$$ (8)

根据劳斯判据,系统的稳定条件为:

①$J_T > j^2 \cdot Z \cdot J_D$;

②$B_T > j^2 \cdot Z \cdot B_D$;

③$K_D > 0$。

一般负载的惯量远大于斗轮的惯量,条件1满足。负载阻尼也要比斗轮的阻尼大,K_D 为斗轮力矩增益也为正值,条件2、3满足,系统是稳定的。

自振角频率为

$$\omega_n = \frac{1}{j}\sqrt{\frac{K_D}{J_T - j^2 \cdot Z \cdot J_D}}$$

阻尼系数为

$$\zeta_n = \frac{B_T - j^2 \cdot Z \cdot B_D}{2 \cdot j\sqrt{K_D(J_T - j^2 \cdot Z \cdot J_D)}}$$

将式(8)写成标准形式为二阶振荡环节

$$\frac{\theta_D(s)}{M_L(s)} = \frac{j}{s^2 + 2 \cdot \omega_n\zeta_n \cdot s + \omega_n^2}$$ (9)

$n = 1$ 时,传递函数的形式不变,ω_n 不变,仅阻尼系数发生变化。则

$$\zeta_n = \frac{K_z + B_T - j^2 \cdot Z \cdot B_D}{2 \cdot j\sqrt{K_D(J_T - j^2 \cdot Z \cdot J_D)}}$$

$n = 2$ 时,负载为非线性,在平衡点附近线性化后,也仅是阻尼系数的变化

$$\zeta_n = \frac{K_0 + B_T - j^2 \cdot Z \cdot B_D}{2 \cdot j\sqrt{K_D(J_T - j^2 \cdot Z \cdot J_D)}}$$

式中 $K_0 = 2 \cdot K_z \cdot \omega_T|_{t=1}$

ω_T —— 额定输出转速。

4 仿真及结论

在以干扰力矩为阶跃信号输入时,幅值在最高同步工况力矩之内,$J_T = 80.4$ N·m,阻尼系数为 $0.4 \sim 0.6$,令 $K_J = \frac{J_T}{j^2 \cdot Z \cdot J_D}$,$Z = 4$ 时,进行动态特性仿真,将式(9)写成输出转速对干扰力矩的传函为

$$\frac{\omega_T(s)}{M_T(s)} = \frac{-1}{s(s^2 + 2 \cdot \omega_n \cdot \zeta_n \cdot s + \omega_n^2)}$$ (10)
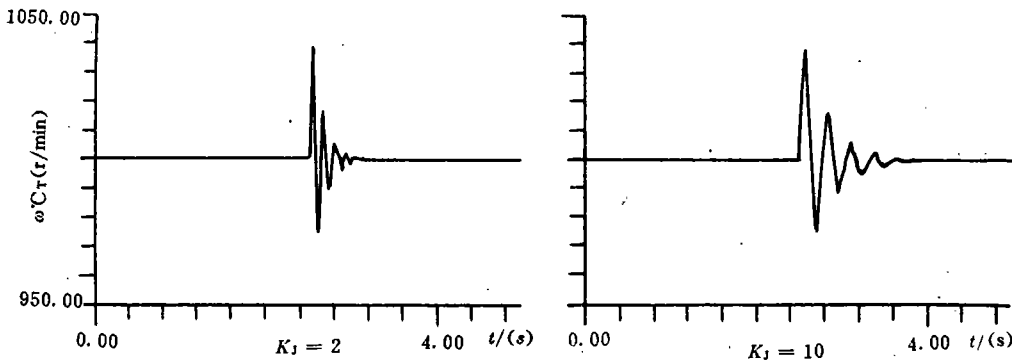
因为存在积分环节,是无差系统,仿真结果见图2。

图 2　仿真结果

由仿真结果看出,斗轮惯量与负载惯量相差较大时,频率较小;而与负载惯量接

近时,频率较高。振幅决定于阻尼系数;阻尼系数不变时,振幅不变,振幅为 4% 左右。高频时过渡时间为 0.7 s,低频时,过渡时间为 1.5 s。系统最终处于无差状态,也就是高效液力偶合器总能处于无滑差的状态运行。所以系统的抗干扰能力强,动态响应快,限矩效果好,是理想的大功率、大惯性传动元件。

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产品介绍

一种新型油田采油工艺加热炉研制成功

一种新型 CWN 型和 WN 型油田采油工艺用火筒式加热炉,由哈尔滨市节能炉窑设备厂研制成功。

该加热炉适用于以原水、含油污水和原油为工质。主要应用在原油加热脱水、原油加热集输、原油加热管输、原油稳定等工艺流程。

该加热炉效率高达(92～94)%,在使用原水、含油污水和原油情况下,年平均运行效率为(85～90)%,节油率(30～40)%,连续运行一年至二年就可回收设备投资。

新设计的 CWN 型高效节能火筒式加热炉系列,其容量比现有油田火筒式加热炉大出两倍。

该加热炉有大、小两个炉胆,大炉胆在前,小炉胆在后,呈偏心串联布置,大炉胆为燃烧室,小炉胆为粗烟管,这种变径炉胆是本加热炉结构独到新颖之处。传统的平炉胆每隔 1 米有一个膨胀环,这是因炉胆的刚性和热膨胀的要求而设,新设计的火筒式加热炉,在串联的大小炉胆后部布置了一个轴向膨胀节,用以吸收大小炉胆的热膨胀量,这一结构型式从技术上打破了多年传统的膨胀结构型式,变多个膨胀节为一个总的集中膨胀节,既便于制造,又可使加热炉容量增大。该加热炉构思巧妙、结构新颖、设计合理,经国内外联机检索,其相关文献为零篇,属国内外首创。

蒸汽供热系统对流水击研究＝A Study on the Convection Water Hammer of a Steam Heat Supply System[刊,中]/Shang Demin, Chen Anbin, et al (Harbin Institute of Technology)//Journal of Engineering for Thermal Energy & Power. -1996,11(4)-193～196

Convection hammering of water and steam often occurring in steam heat supply systems such as water/steam pipings, water storage vessels and steam drums is one of the most common malfunctions leading to the instable operation of boilers and steam supply equipment. The present paper analyses the thermodynamic cause of the convection water hammer and presents a method for calculating its speed and intensity with results of calculation being given for some specific examples. **Key words:** boiler, convection water hammer, thermodynamics

回热加热器的散热对机组热经济性的影响＝The Effect of Heat Release of a Regenerative Heater on the Economics of a Steam-Electric Generating Set[刊,中]/Li Luping (Changsha Electrical Engineering Institute)//Journal of Engineering for Thermal Energy & Power. -1996,11(4). -197～200

By the use of an equivalent heat drop method an analysis was performed of the effect of regenerative heater heat release on the thermodynamic economics of a turbine-electrical generating set with the conception of an effective steam extraction factor being proposed, The effective steam extraction facfor can be employed to evaluate the effect of the heater heat release loss on the thermodynamic economics of the above-cited generating set. **Key words:** turbine-electrical generating set, regenerative heater, equivalent heat drop, effective steam extraction factor

热电联产热电分摊新概念＝A New Conception on the Apportionment of Heat and Electricity for a Cogeneration Plant [刊,中]/ Wang Shizhong (Nantong Cogeneration Plant)//Journal of Engineering for Thermal Energy & Power. -1996,11(4). -201～204

Proceeding from a calorimetry method and by way of multi-layer analysis the author has come up with a new conception of apportionment. Through a mathematical derivation obtained is the mathematical expression of an actual enthalpy drop method (also called internal work method), which features conception clarity, a clear-cut physical meaning and compliance with the principle of integrity, thus ensuring the economic benefits of both the heat and electricity producers. **Key words:** cogeneration, apportionment ratio of heat and electricity based on quality, steam extraction heat supply unit, steam extraction power generation

高效液力偶合器的动态特性分析＝Dynamic performance Analysis of a High-efficiency Hydraulic Coupling [刊,中]/Wang Liwen, Xie Wenlan, et al (Harbin Institute of Technology)//Journal of Engineering for Thermal Energy & Power. -1996,11(4). -205～208

This paper analyses the dynamic performance of a high-efficiency hydraulic coupling transmission system and studies the transfer function under three kinds of basic loading modes. Through the analysis of

simulation results the capacity for coping with load fluctuations has been identified. **Key words**: high-efficiecny hydraulic coupling, dynamic performance, hydraulic transmission system

燃用混煤电站锅炉结渣原因分析及结渣趋势的模糊预测 = An Analysis of the causes of Boiler Slagging at a Mixed Coal-Fired Power Station and a Fuzzy Prediction of the Slagging Tendency [刊, 中]/Guo Jia, Zeng Hancai (Huazhong University of Science &. Engineering) // Journal of Engineering for Thermal Energy &. Power. -1996,11(4). 209~212

In connection with a new problem of firing a coal mixture comprising two kinds or more than two kinds of coals of different properties analysed in this paper are the causes of slag formation for such coal mixture with its slagging tendency being predicted by the use of a fuzzy cluster analytical method. On this basis pertinent procedures and measures are proposed to cope with the above-cited problem. **Key words**: coal, combustion mixture, slagging cause analysis, fuzzy prediction, preventive measures

双回流燃烧器实验研究与应用 = Experimental Study of a Dual Return-flow Burner and Its Application [刊, 中]/Qiu Jihua, Chen Gang, et al (Huazhong University of Science &. Engineering) // Journal of Engineering for Thermal Energy &. Power. -1996,11(4). -213~216

In view of the existing problems related to the firing of low-grade coals in home-made utility boilers, such as ignition difficulty, instable combustion and low combustion efficiency, etc the authors have proposed a new type of direct flow burner capable of producing both and inner an outer return flow zone. Its laboratory cold and hot-state test results are analysed and discussed followed by a brief description of the industrial use of such burners. **Key words**: burner, combustion, boiler

新型燃用无烟煤的 CUF 锅炉冷态模化试验研究 = An Experimental Study on the Cold-stare Simulation of an Anthracite-fired New Type CUF Boiler [刊, 中]/ Zhang Xuan (Suzhou Thermotechnical Research Institute) // Journal of Engineering for Thermal Energy &. Power. -1996,11(4). -217~221

A new type CUF boiler developed for the firing of low-volatile anthracite combines the merits of four-corner tangential firing and vertical firing. An experimental study was conducted of the CUF boiler performance through the use of a cold-state simulation method. The in-boiler aerodynamic field and horizontal flue duct gas speed distribution at the furnace outlet was measured. The test results show that the CUF boiler has marked superiority in terms of anthracite ignition improvement, combustion stability and burn-down as well as a satisfactory performance characterized by the absence of furnace slagging and a uniform flue gas speed at the furnace outlet. **Key words**: anthracite, cold-state simulation, CUF boiler

以流化床换热回收柴油机废气余热的试验研究 = An Experimental Study on the Recovery of Diesel Exhaust Heat by the use of a Fluidized Bed Heat Exchanger [刊, 中]/Li Jianhong, Zhu Shiwei