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面向智能维护的嵌入式无线预诊断智能体技术

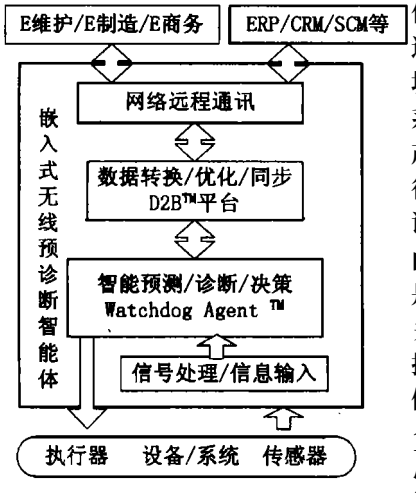
张　蕾[1]，曹其新[1]，李　杰[2]，张春余[1]，张静永[1]
(1.上海交通大学　机器人研究所,上海　2000030;
2.美国威斯康星大学　智能维护中心,密尔沃基　WI53224)

摘　要:介绍了嵌入式无线预诊断智能体(ETPA)的发展现状,深入分析了设备性能退化评估技术、数据转换、优化和同步技术、无线通讯技术、嵌入式系统与 SoC 技术几项实现 ETPA 的关键技术,介绍了 D2B™平台和 Watchdog Agent™等基础研究成果,提出了利用 GPRS 实现 ETPA 无线数据传输的新方式。最后展望了 ETPA 在不同行业的应用前景。

关键词:智能维护系统;嵌入式智能体;无线数据传输
中图分类号:TH16;TP391　　文献标识码:A

随着竞争全球化趋势的发展,传统制造业面临新的问题和挑战,一方面企业竞争的焦点已经由产品质量和生产率转向产品服务水平,用户越来越注重生产商所提供的服务支持。另一方面,传统的设备维护由于采取故障发生之后维护人员奔赴现场的方式,无论对生产商还是对用户来讲,都是很不经济的。但同时,信息技术和网络的飞速发展又给制造业解决这些问题带来了机遇,生产商通过提供智能维护工具,可以对设备的"健康"状况进行全天候的远程监控,实现设备近乎"零故障"的高质量运行,这就是已成为当前研究热点的基于网络的智能维护技术[1~2]。

怎样在现有设备的基础上,使其稍加改造,便能满足智能维护的要求呢?目前比较一致的共识是开发一种嵌入式无线预诊断智能体(Embedded Tether-free Prognostic Agent,简称 ETPA),ETPA 结合了嵌入式系统、人工智能及无线通讯等多项技术,可以嵌入或集成在被监控设备中,达到既对设备和工作环境影响尽量小,又能实现其改造的要求。ETPA 的基本模块如图 1 所示,主要功能是对设备的性能状况进行评估和预测,防止意外故障和失效,实现设备的"智能化"。同时,ETPA 还要通过其通讯模块及时与远程维护系统、决策系统和产品设计中心等进行信息交互,实现设备的"网络化"。由此可见,ETPA 是实现智能维护的关键,也是智能维护先进理念的具体体现。



▲图 1　嵌入式无线预诊断智能体示意图

1　ETPA 的发展现状

智能维护作为一个全新的理念,在国外的发展历史也不过才几年,因此,ETPA 的开发尚处于初级阶段,目前一些远程监控和诊断模块已构成了 ETPA 的雏形。例如由 Intel、Philip 等 13 家半导体制造商组成的国际性协作组织 SEMATECH 成立了 E-Diagnostic 项目组,在半导体生产设备上加入一智能诊断模块,实现设备制造厂家对产品的远程技术支持与服务。最新的 Pratt &Whitney 喷气式飞机的发动机上装有一系列"舱内诊断器",能够和地面系统相结合,提前几个月预测发动机是否需要维修。制造业中的数字化工业装备,如 Siemens、Mazak、OKUMA 等公司推出的新型数控产品,都带有远程诊断接口,具备一定的网络集成能力。这些接口和模块可以实现数据的采集、监测和诊断等功能,在一定程度上可满足远程监控与诊断的要求,但是可以看出,以上这些模块的功能比较单一,智能化水平还比较低,而且各个公司只针对各自的产品,比较独立,不具备开放性和通用性,尚不能满足实现智能维护的要求,因此,结合当前无线通讯的迅猛发展趋势及其优点,开发成本低廉,通用性好,智能化程度高的嵌入式无线预诊断智能体已成为迫切的需要。

2001 年,在美国 NSF 资助下,美国威斯康星大学联合 Intel、Ford Motor 等著名大公司,成立了智能维护系统(IMS)中心,确立了智能维护的基本理论框架和指导思想,其中提出的研究重点之一就是嵌入式无线预诊断智能体[3]。如今 IMS 中心已经成为国际上智能维护领域研究的领头羊。在国内,上海交通大学和威斯康星 IMS 中心正开展合作,对智能维护的相关领域进行研究和开发,旨在紧跟国际趋势,肩负起在国内传播和创新智能维护知识的重要角色。

2　实现 ETPA 的关键技术

2.1　设备和产品的性能退化评估技术

在故障发生之前,设备零部件一般要经历一系列的退化状态。智能维护区别于故障诊断的关键之处就在于通过 ETPA 中的预诊断算法对设备性能退化进行评估和预测,从而预防了故障的发生。虽然智能维护与故障诊断的基本理念有本质的区别,但传统的故障诊断方法也可以被借鉴和利用,例如信号处理中的时域和频域分析、快速傅立叶变换、小波分解,决策方法中的专家系统和神经网络等,这些已经比较成熟的理论和方法都为设备性能评估技术的研究提供了良好的基础。相对来讲,性能退化评估更应该注重以下两个方面:

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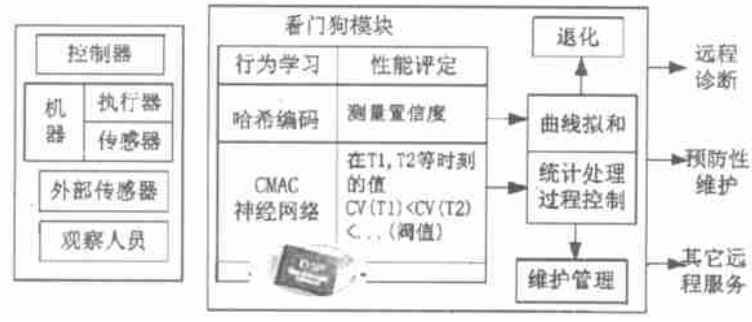
预测方法:国内外很早就开展了对机械设备状态预测方法的研究,Box,Jenkins 提出的时序模型 ARMA(Auto Regressive Moving Average)模型是最早也是最成熟的方法[4]。近几年来,基于小波分解、灰色理论、神经网络等的智能预测方法发展迅速,并且在不同领域得到了广泛的应用[5]。1996 年,Jay Lee[6]把神经网络预测技术应用于设备性能退化分析上,扩展了神经网络在这一领域的应用。目前其率领的智能维护中心在性能预测方面,针对不同的应用,又相继提出了几种不同的方法,例如逻辑回归和小波神经网络预测算法[7~8]。

信息融合:由于设备的复杂性,某项性能的退化可能产生不同的症状,例如轴的不平衡可能表现为振动、温度波动,可用不同的传感器进行检测。同样,一种传感器有时也可同时检测几种不同类型的性能变化。因此,在数据层、特征层及决策层上采用信息融合技术,综合考虑多个传感器的信息,才能提高设备性能评估的有效性[9]。

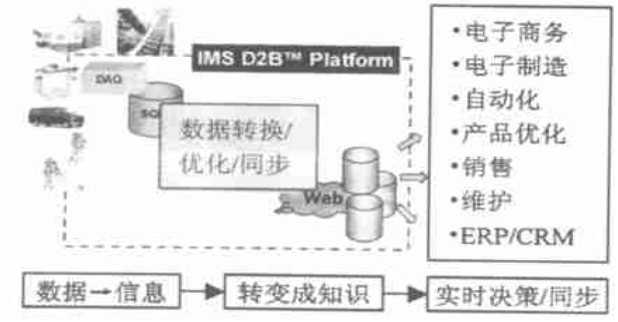
智能维护中心开发的性能退化评估工具——智能看门狗代理(Watchdog Agent™)如图 2 所示,可以看出,ETPA 是在看门狗代理的基础上提出来的,是看门狗代理和其它模块相集成的结果,在 ETPA 中,看门狗代理作为一个模块不仅要实现智能预测和诊断功能,还将协同下一节中介绍的 D2B 平台与远程系统进行信息交互。

2.2　数据转换、优化和同步技术

为了和现有的企业商务系统(客户关系管理 CRM,供应链管理 SCM,企业资源计划 ERP 等)进行信息交互,需要有一个平台对获得的设备性能信息进行进一步的转换和优化(例如网页浏览的 XML、HTML 格式,数据库查询的 SQL 格式等),以实现信息在高层的共享。为此,智能维护中心提出了 Web 驱动的数据处理平台 D2B™(Device to Business),如图 3 所示。D2B 平台集数据的转换、优化和同步为一体,数据转换为网络层可用的格式后,分布在不同地点的生产商和用户可以通过 Web 工具分享这些信息,执行许多 Web 驱动的应用程序。另外,通过 D2B 平台可实现设备层到商务层的直接对话。例如,当刀具磨损之后,信息可以直接从加工中心发送到刀具供应商,要求定购刀具。这时,刀具生产商出售的不再是刀具本身,而是刀具的切削时间,从而使企业利润由制造向服务转移。



▲图 2　智能看门狗代理



▲图 3　D2B 平台

D2B 平台体现了 ETPA 与高层系统进行信息交互的"智能"特性。目前,D2B 平台尚处于开发初期,怎样根据远程系统对信息的实际需要,对数据进行压缩和提取,以及怎样将设备性能信息进行合理地表达,转换成专家系统或其它决策系统所需的知识表示的方式,怎样协调和同步不同系统作出的决策,有待于深入研究和探讨。

2.3　无线通讯技术

在过去的 5 年里,无线技术对移动电话、网络计算和通讯业的发展产生了极大的影响,也给传统制造业向信息化和电子化转变带来了机遇。无线技术在工厂中的应用被《财富》杂志评选为影响未来制造业的三大热点技术之一[10]。2001 年 10 月,"无线技术用于 E 制造,E 维护和 E 服务"的专题会议在美国威斯康星州举行,来自工业界和学术界的 150 多家代表参加了会议,讨论了无线通讯技术给制造业所带来的巨大潜力和革新。

根据不同无线通讯方式的特点及当前的发展趋势,我们提出了在智能维护中采用 GPRS 无线数据传输的新方式。构架在传统 GSM 网络之上的 GPRS 技术(General Packet Radio Service)按照标准的 UDP,TCP 网络协议传输数据,是实现 GSM 向 3G 过渡的重要技术,在无线通讯中越来越受到重视。目前全球已有近百家运营商开通了 GPRS 商用系统,试商用系统或试验系统,国内的各大通讯公司也已经开通了相关服务,为 GPRS 的广泛应用提供了可靠的保证。图 4 是我们开发的利用带有 GPRS 的 PDA 进行数据传输的模块,左端是模拟的要传递的信息,右端是客户端通过服务器得到的数据信息和曲线。试验证明,GPRS 完全能满足智能维护中信息传输的需要,并且具有以下几点优势:

(1)　传输速率高

最高速率可达每秒 115k 比特;

(2)　接入时间短

在通信的过程中不需要建立和保持电路,呼叫建立时间很短。这一点非常适合为远程设备提供快速即时的连接;

(3)　资源利用率高

由于采用分组交换模式,设备只有在发送或接收数据期间才占用资源,这意味着多个设备可高效率地共享同一无线信道;

(4)　费用低廉

GPRS 用户的计费以通信的数据量为主要依据,体现了"得到多少、支付多少"的原则。设备与网络的连接时间可能很长,却只需支付相对低廉的连接费用;

(5)　随时随地,永远在线

只要设备一开始工作就可以上网,达到时时在线。

2.4　嵌入式系统与 SoC 技术

由 ETPA 的功能和应用背景可知,ETPA 应该具有体积小,可靠性高,可移植性好等特点。因此 EPTA 一般选用嵌入式 PC 作为硬件平台,嵌入式 PC 与一般 PC 具有良好的兼容性,可借鉴和移植大量成熟的基于普通 PC 的设备监测和诊断技术。嵌入式 PC 的数据处理能力、通信能力和界面友善程度已达到相当高的水平,能同步应用无线通讯技术、蓝牙技术、视频技术等比较先进的网络通讯技术,以此作为硬

件基础的 ETPA 具备系统扩展性好、标准化和模块化程度高等优点。

以软硬件协同设计,IP 核复用和超深亚微米等技术为支撑的系统芯片(System on Chip,简称 SoC)技术正成为目前集成电路设计最先进和最热门的领域。SoC 设计系统的核心思想是除了那些无法集成的外部电路或机械部分以外,其他所有的系统电路全部集成在一起,这必然使复杂智能芯片的设计成为可能,为 ETPA 向微型化、集成化发展提供了物理基础。ETPA 中的智能算法完全可以以 IP 软核形式存在,而且通过更改 IP 软核的参数可以使 ETPA 适应于不同类型的设备和应用场合,大大提高了 ETPA 的可重构性。IP 智能软核可作为设备的可选附件出售,在顾客需要和购买时再烧入到芯片中,十分简单方便。而且随着 SoC 技术的发展和完善,完全有理由相信,在不久的将来,基于 SoC 技术的 ETPA 的成本将会很低,不会过多地增加设备成本。

▲图 4 基于 GPRS 的无线数据传输

3 ETPA 应用前景及意义

ETPA 具有非常广阔的应用前景,在以下几个领域中将大有用武之地。

(1) 传统制造业

如柔性制造系统、大型加工中心等,ETPA 是对传统制造设备进行改造,实现传统工业信息化的重要途径。

(2) 电子产品制造业

如芯片封装和半导体行业,随着芯片体积变得越来越小,芯片加工设备稍有误差,就会导致产品废品率上升,即使 Intel 和 IBM 这样的大公司也不得不面对这一问题。近几年,随着 AMD,Intel 等国际知名芯片制造厂商进入我国,电子制造业的产值在国民生产产值中所占比重日益突出,由于设备投资大,而且多是进口,任何设备故障都会造成严重的损失,因此,在这一领域开展基于 ETPA 的智能维护具有重要意义。

(3) 交通业

Pratt &Whitney 喷气式飞机就是很好的例子,带有 ETPA 的飞机可以根据各部件的性能情况,辅助航空公司制定零部件的更换计划,从而降低了检查和维护成本,ETPA 与地面分析系统相结合,也能减少如航班延误、取消、更改等意外事故带来的损失。当今汽车制造业也正在寻求将信息远程处理模块嵌入汽车的方法,以实现自动路旁辅助导航。通用为此制定了一个目标:到 2005 年,计划在其所有汽车上装备带有“OnStar”远程信息服务功能的软硬件。

(4) 其他行业

医疗器械、信息家电、电梯、打印机等与人们日常生活密切相关的各类产品。

根据比较保守的预算,智能维护可以使设备运转能力增长 2.5 %～5 %,这就意味着价值 2 亿美元的设备,每年可多创造 500 万美元的价值,作为世界上最大的电梯制造公司 OTIS 为此每年能节省 5 亿美元的开支。据统计资料显示,我国正逐渐成为世界重要的制造业基地之一,但目前我国 90 %以上高档数控机床、100 %的光纤制造装备、85 %的集成电路制造设备、70 %的轿车工业装备依赖进口,远距离跨国维修方式既影响生产,又增加运作成本,设备智能维护肯定会变得越来越迫切。因此,开发 ETPA,在实现 ETPA 的关键技术上进行重点研究和攻关,为实施智能维护提供支持具有重要的意义。

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作者简介:张蕾(1975 -),女,上海交通大学博士研究生,主要从事基于网络的设备远程监控、智能维护等方面的研究。

HE Gang ,LI Bai-lin
(School of Mechanical Engineering ,Southwest Jiaotong University ,Chengdu 610031 ,China) P45

Abstract: Graphics sharing is one of key contents for CSCD. This paper analyses the characters and technologies of graphics sharing ,and produces a realizable project on the basis of summarizing the characters of graphic sharing. This paper has instructive significance for reseach on graphics sharing technology and establish graphics sharing system.

Key words: CAD; collaborative design; graphics sharing; network

Innovative Design of Computer Aided Surgical System for Total Knee Replacement

ZHAGN Wen-qiang ,HUANG Xue-mei ,WANG Cheng-tao
(School of Mechanical Engineering, Shanghai Jiao-Tong University ,Shanghai 200030 ,China) P48

Abstract: Conventional Total Knee Replacement (TKR) surgery is difficult to manipulate with a series of jigs and fixtures and hard to align the mechanical axis of femur. In this paper ,a computer aided surgical system for TKR is developed in laboratory, which consists of articulated manipulator and mechanical support arm driven by the servo motor. The performance of prototype shows that the compact mechanisms solve the above problem absolutely and lead convenience to surgeons.

Key words: computer aided surgery; TKR ,articulated manipulator

Design and Principle of Smart Magnetorheological Fluid Damper

XIONG Chao[1] , ZHENG Jian[1] , ZHANG Jin-qiu[1] , LU Jian-gang[1] , GAO ting[2]
(1. 1st department Ordnance Engineering College , Shijiazhuang 050003 China ; 2. BAICHENG weapons experiment center , Baicheng 137001 China) P50

Abstract: In the paper ,the structure and principle of Magnetorheological fluid (MRF) damper were introduced. A set of key design issues and their solutions about winding enwinding mode, structure parameters and magnetism path of MRF damper were concluded. By experiments on the MRF damper , its characteristic was analyzed , and the validity of the design method was validated.

Key words: MRF; damper; structure design; magnetism path

Numerical Analysis of Static Performance for Ultra Precision Spindle Supporting by the Aerostatic Bearing

YANG Fu-xing[1] ,DONG Shen[2]
(1. School of Automation , Beijing University of Posts and Telecommunications , Beijing 100876 , China ; 2. School of Mechanical and Electrical Engineering , Harbin Institute of Technology , Harbin 150001 ,China) P54

Abstract: To evaluate the static performance of the ultra precision Spindle ,the finite element models were used to caluclate pressure distribution in the aerostatic bearing. The weight , stiffness and the supply air flow of aerostatic journal and thrust bearing were evaluated. Study the effect of bearing parameters on the static performance of the aerostatic bearing. The design rules for aerostatic bearing were proposed. The load ,radial stiffness , axial stiffness and angular stiffness of precision spindle were formulated. The analysis method was tested to be right by the experiments.

Key words: aerostatic bearing; spindle; finite element method ; numerical analysis

Application of GA to Optimizing the Welding Path With Minimum Distortion

YANG Hu ,SHAO Huo
(School of Mechanical Engineering ,Shanghai Jiao Tong University ,shanghai 200030 ,China) P57

Abstract: The optimal welding path should be able to minimize the general distortion and consequently improve product 's quality. In this paper ,A thermo-mechanical model is developed to estimate welding distortion ,and the genetic algorithm (GA) is applied to optimize the welding path. Finally ,a welding path optimization process based on the suggested strategy is demonstrated.

Key words: genetic algorithm ; distortion calculation ; finite element analysis ;path scheduling

Study of Tolerance Conformance Test of Square Openings

WANG Yu , YANG Li-ping , WU Wei-guo , MA Yu-lin
(Depatment of Mechanical Engineering , Harbin Institute of Technology , Harbin 150001 ,China) P60

Abstract: Tolerance Conformance Test between dimension tolerance and geometric tolerance is an indispensable part of Computer-Aided Tolerancing Design. According to the tolerance rules of ER , MMC and LMR of national standards , tolerance conformance test of square openings is carried out. Its results are some mathematically equivalent formulas. Also , an example is used to verify the practicability of these methods. So the paper provides an executable method for the conformance evaluation of Computer-Aided Tolerancing Design.

Key words: computer-aided tolerancing design ; tolerance conformance test ;tolerance consistence

Research on the Model for Producing the Precise Die of Parabola Gyre Surface

YUAN Jian-ping[1] ,SONG Yun[2] , TANG Yu-yong[2]
(1. Journal of Natural Science , Heilongjiang University , Harbin 150080 , China ; 2. School of Science , Harbin Institute of Technology , Harbin 150001 ,China) P62

Abstract: The parabola gyre surface has been used widely , because of its special optical prop-erty. To produce the precise dies in batch with NC machining ,the machining scheme using flat-end milling cutter for 3-axis NC machining is given. Also , the cutting tool parameters ,the machining row space and the integrated mathematical model of horizontal and axial feed speed are presented. Then the feasibility and reliability of scheme , model and formula are proved with examples. Therefore ,it could provide a broad reference for producing the dies of the optical mirror in a batch.

Key words:parabola gyre surface ;NC machining ;geometric reverse

Embedded Teher-free Prognostic Agent for Intelligent Maintenance System

ZHANG Lei[1] , CAO Qi-xin[1] , JAY Lee[2] , ZHANG Chun-yu[1] , ZHANG Jing-yong[1]
(1. Research Institute of Robotics , Shanghai Jiao Tong University , Shanghai 200030 , China ; 2. Research Center of Intelligent

Maintenance Systems, The University of Wisconsin-Milwaukee, Milwaukee WI 53224, USA) P64

Abstract: The research status of ETPA (Embedded Tether-Free Prognostic Agent) was introduced, and several critical technologies for developing ETPA, including performance degradation assessment, data transformation, optimization and synchronization, wireless communication, embedded system and SoC (System on Chip), were analyzed. The fundamental research results, such as D2B™ (Device to Business) platform and Watchdog Agent™, were discussed. A new way for tether-free data transmission based on GPRS in ETPA was developed. At last, a prosperous future of ETPA application in several fields was given.

Key words: intelligent maintenance system; embedded agent; teher-free data transmission

Application of Fault Tree Analysis(FTA) to the Manufacture of Turbine Gas Meter

Li Xue-wei, Zou Hui-jun
(School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200030, China) P67

Abstracts: Fault Tree Analysis (FTA) is a better way to analyze the security and reliability of complex system. By applying FTA to the assemble process of turbine gas meter, not only the assemble quality can be both qualitatively and quantitatively analyzed, but also the possible assemble problems may be solved by considering the system failure reasons.

Key words: turbine gas meter; Fault Tree-Analysis

Transient Temperature and Stress Analysis for Thermo-viscoelastic SRM Grains

XU Xin-qi, HU Ming-yong
(Naval Aeronautical Engineering Academy, Yantai 264001, China) P69

Abstract: The transient temperature distribution in a solid rocket motor grain due to the effect of environment temperature is calculated with finite element method. Based on the viscoelastic integral constitutive relation, the thermal stress and strain distribution is also calculated. The variation curve of stresses and strains with time for dangerous node on the interface of insulating layer and the SRM grams is presented. It provides scientific basis for structural integrity analysis.

Key words: propellant grain; temperature distribution; stress-train analysis; finite element method

Optimization Design of Inertial Vibrating Conveyer for Energy Efficiency

CHEN Dian-hua, SHANG Gui-zhi, LI Yu-guang
(Department of Mechanical Engineering, Dalian University, Dalian 116622, China) P72

Abstract: This paper discusse-d the optimization design of the inertial vibrating conveyer under the best energy efficiency of conveyer as its objective function. The mathematical model for optimal design, which was very according with the operating mode, has been developed. The optimal analysis has been accomplished using the method of nonlinear programming with constraints. The advantage of this design method has been proved by an example. The result indicates that energy efficiency of the conveyer can be improved a lot by using optimized working parameters and structure parameters.

Key words: energy efficiency; optimization design; inertial vibrating conveyer

Modeling and Dynamic Analysis of Roller Coaster Using Virtural Prototype

ZHENG Jian-rong[1], WANG Hui-qun[1,2]
(1. College of Mechanical Engineering, East China Universuty of Science and Technology, Shanghai 200237, China; 2. Shanghai College of Electricity & Machinery Technology, Shanghai 200240, China) P74

Abstract: The dynamic characteristic is one of important factors that influence the performances of large-scale roller coasters. This paper deals with analysing dynamic performance of roller coasters by using virtual prototype. The main techniques of modeling a virtual prototype were presented, e. g. model of railway and vehicles, constraints between railway and vehicles, adding frictions, applying the autocontrold brade etc. A virtual prototype of roller coaster was constructed and simulated by using ADAMS software. The location, velocity, acceleration of the vehicles and forces of the roller coaster during moving were analyzed and the dynamic performances were obtained. This provides a new means for the design and the perfomance estimation of roller coasters.

Key words: roller coaster; virtual prototype; ADAMS; modeling; dynamic analysis

A Modern Friction Clutch

LIANG Yi-de
(Institute of Mechanical Engineering, Xiangtan University, xiangtan 411105, China) P78

Abstract: This paper introduces a modern friction clutch whose equivalent friction coefficient is 10～30 times larger than that of the common friction clutch, so the volume is small, power transmitted is great, the structure is simple. Besides, it also has good technological behaviour, cheap cost and long-life. Therefore, this is an ideal friction clutch of modern version.

Key words: mordern version; friction, clutch

Optimization Design of Impression Driving System of One-turn Cylinder Press

CHEN Chang-xian, ZHANG Xiao-ling
(Department of Mechatronic Engineering, Beijing Institute of Graphic Communications, Beijing 102600, China) P80

Abstract: The driving system of cylinder and impression bed of the one-turn TY401 cylinder press is composed of the four-bar linkages and the crank and linkage mechanism. Its motion cycle is introduced and computed. And the optimization design method of the system is discussed by way of setting-up of the CAD model. The conclusion derived in the thesis paves the way to develop new models of presses of the same kind.

Key words: cylinder press; driving system; optimization design