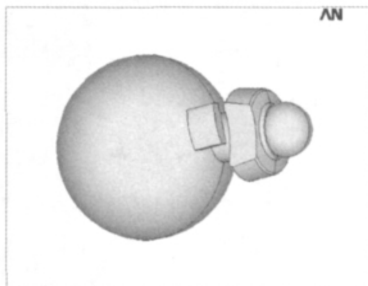
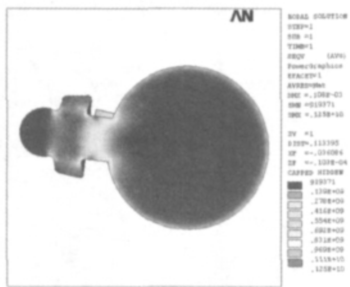
9(a)所示的一体化几何模型,在施加相同载荷和边界约束条件的前提下,对模型进行了模拟计算,有限元分析结果如图 9(b)所示。



(a)几何模型



(b)米塞斯应力分布云图

图 9 增设辅助承载机构的几何模型与应力分布图

模型中的最大位移值为 0.108 mm,最大米塞斯应力为 0.125×10^4 MPa,约为原模型最大应力的百分之二十八,说明增设辅助承载结构能进一步大幅降低拨转轴内的应力水平。

6 结论

可控冲击矛施工曲线轨迹孔时拨转轴的承载状况最为恶劣,为其危险工况;拨转轴与矛头连接处为危险截面。拨转轴断裂的原因是应力集中和疲劳共同引起的。拨转轴与矛头连接处退刀槽的存在导致应力高度集中,疲劳破坏的产生是由冲击矛自身依靠高频脉动载荷工作的性质所决定的。

有限元分析结果表明:优化拨转轴的结构(增大其与矛头连接部位的直径,取消连接部位的退刀槽)和增设辅助承载机构都能明显降低拨转轴内的应力水平和应力集中程度,减小拨转轴的变形量,从而有助于提高拨转轴的使用寿命,可有效避免其出现脆性疲劳破坏。

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工程机械分布式控制系统 CAN 总线节点设计

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摘 要:将 CAN 现场总线技术应用于工程机械分布式控制系统中,提出了该分布式控制系统的结构模型,在此基础上,详细介绍了人机界面节点、主操作台节点及其它子节点的具体功能及结构特点;为简化系统硬件设计及提高系统抗干扰性能,采用 TI 公司高性能的 16 位 DSP TMS320LF2407 作为核心器件来实现工程机械分布式控制系统的设计,利用 TMS320LF2407 芯片内置的 CAN 控制器来构成 CAN 总线网络;完成了系统各个节点的硬件设计,并在硬件上采用光电隔离的方法,以防止从 CAN 总线上窜入的干扰信号;完成了各节点的软件设计,并在软件上采用定时测试的方法来保证通信过程中数据传输可靠。通过模拟试验对各节点间通信的稳定与可靠性进行了检验。试验结果表明:该分布式控制系统软件及硬件稳定可靠,主节点能够与子节点间进行可靠的数据传输与通信,实现了在线远程监控。

关键词:工程机械 分布式控制系统 CAN 总线 DSP 主节点 子节点

CAN 总线是国际上应用最广泛的现场总线之一,最初被设计用作汽车电子控制单元(ECU)的串行数据传输网络,现已被广泛应用于欧洲的中高档汽车中。近几年来,由于 CAN 总线极高的可靠性、实时性,CAN 总线开始进入中国各个行业的数据通讯应用领域,并于 2002 年被确定为电力通讯产品领域的国家标准。

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CAN-bus 总线的适用范围：可适用于节点数目多、传输距离在 10 km以内、安全性要求高的场合。也可适用于对实时性、安全性要求十分严格的机械控制网络[3]。

由于 CAN-bus 总线的良好性能，特别适合于工程机械中各电子单元之间的互连通讯。随着 CAN 总线技术的引入，基于 CAN 总线的分布式工程机械控制系统取代原有的集中式控制系统，传统的复杂的线束被 CAN 总线所代替。工程机械控制系统中各种控制器、执行器以及传感器之间通过 CAN 总线连接，系统线缆少，敷设容易，成本低，而且系统设计更加灵活，信号传输可靠性高，抗干扰能力强。

目前 CAN-bus 总线技术在工程机械上的应用越来越普遍。国际上一些著名的工程机械大公司如 CAT、VOLVO 和利勃海尔等都在自己的产品上广泛采用 CAN-bus 总线技术，大大提高了整机的可靠性、可检测性和可维修性，同时提高了智能化水平。在国内，CAN-bus 总线控制系统也开始在工程汽车的控制系统中广泛应用，在工程机械行业中也正在逐步推广应用。

本文将 CAN 现场总线技术应用于工程机械分布式控制系统的设计，采用内置 CAN 控制器的 DSP 完成各控制子系统的功能，又通过 CAN 总线传送数据或命令，实现功能分散，集中监视，危险分散。

1 工程机械分布式控制系统总体框架

1.1 系统结构

本设计采用的工程机械分布式控制系统结构如图 1 所示。该结构采用现场总线式集散系统，它由主节点（人机界面节点及主操作台节点）、各子节点（控制器 1、2…n）并配以 CAN 现场总线控制网络构成。这种结构比环形结构吞吐率低，但结构简单，成本低，且无源抽头，系统可靠性高；信息的传输采用 CAN 通信协议；为有效抗共模干扰，传输介质采用双绞线；各节点的微控制器均使用 TI 公司生产的定点 DSP（TMS320LF2407 芯片），使节点小型化。

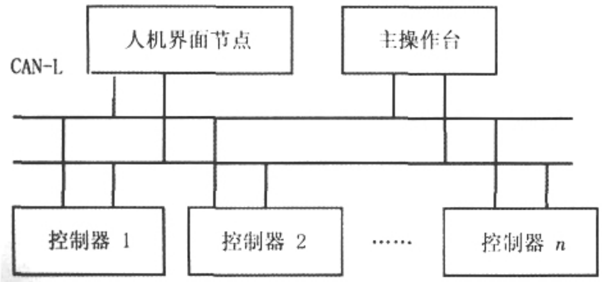

图 1 工程机械分布式控制系统结构

各节点控制器采用全封闭轻铸铝外壳，表面喷丸涂漆，内部用灌封胶灌封，保证电路板不受环境、机械和电气的影响。接口采用 AMP 插件，镀金插针，自锁全封闭，防护等级 IP67，保证控制器长期在恶劣条件下正常可靠的工作[6]。

1.2 节点功能

节点设置方面，人机界面节点设置为 1 号上位节点，主操作台节点设置为 2 号上位节点，控制器 1 为 1 号子节点，控制器 2 为 2 号子节点，依此类推，各节点在整机控制系统中的作用如下[6]：

(1) 人机界面节点：基本上不参与系统的实时控制，它主要完成对各节点的在线监视及对各节点返回信息的分析处理，将处理的结果以各种方式显示于液晶显示屏上。该节点采用高亮度 LCD 显示器，直观形象地显示工程机械的实时工况、操作和故障，可采用一个主画面、多个子画面的分级显示方式。各画面上用图形、图标、动画、图表、曲线等方式来表现各参数。

(2) 主操作台节点：1 个 I/O 节点，用于整机控制，对节点发出控制命令以控制节点工作模式。主操作台设置有各类操作按键、手柄电位器和发光二极管指示灯输出点。主操作台完成对这些输入点的采集，同时对开关量进行延时去抖，对模拟量进行剪切，去头去尾，校正滤波。本节点把这些输入信号组织成数据帧，在各数据帧所属开关量、模拟量发生变化时，将其推送到总线，在其它情况下不占用总线资源。节点的输出信号从总线接收，并通过节点输出。

(3) 其余节点（控制器 2，3，…，n）：具体需要多少个子节点及各子控制器需要实现什么控制功能，应根据实际情况综合考虑确定。这些子控制器只能实现对本子系统的控制，但是其受到主操作台节点的控制，可根据主操作台命令来完成对该子系统的控制以及各子控制器与主控制器、子控制器与子控制器之间的实时数据交换。

1.3 功能特点

基于 CAN 总线的工程机械控制系统，具有下述特点[6]：

1) 基于 CAN 总线的全分布式控制
2) 图形化的人机界面，按键或键盘控制
3) 对系统各项参数的实时检测
4) 机电液实时故障自检

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5) 实现远程状态监视和故障显示

6) 各控制器作为独立的 CAN 节点，各节点间互不影响

2 通讯模块设计

2.1 硬件设计

DSP TMS320LF247 内置 CAN 控制器，使用芯片内置的 CAN 控制器构成 CAN 总线网络，大大简化了硬件连接，DSP 与 CAN 总线的接口电路如图 2。硬件电路中使用 PCA82C250T 是为了增大通信距离，提高系统的瞬间抗干扰能力，保护总线，降低射频干扰（RFI），实现热防护等；高速光耦 6N137 与 TMS320LF2407 及 PCA80C250T 构成光电隔离电路，可有效防止从 CAN 总线上窜入的任何干扰信号，从而提高了系统抗干扰能力。本设计中，光耦部分电路所采用的两个电源 VCC 和 VDD 必须完全隔离。电源的完全隔离采用小功率电源隔离模块或带有多个 5 V 隔离输出的开关电源模块实现，这些部分虽然增加了节点的复杂性，但却提高了节点的稳定性和安全性。为了保证系统能够可靠工作，电路中采用宽电压输入隔离（隔离电压 1 000 VDC）稳压双输出型 DC/DC 模块给系统供电。为确保系统的安全，可在 DC/DC 模块及系统的前端接 TVS、共模扼流圈、极性保护，以防止雷击、浪涌和极性反接。

2.2 软件设计

多节点通信系统主节点和子节点，相互之间都应符合一定的规范，因此需人为地制定一些协议，这些协议是主、子节点双方共同遵守的规定。协议制定的优劣对通信的灵活性和质量有直接影响。为确保通信的可靠性，系统采用点名的方式对各控制器节点定时进行检测，每隔一段时间发送 1 个测试符，当各控制器接收到此测试符后，立即按原数字返回，这样确保了数据传输的可靠性。

(1) 主操作台节点通信程序 流程图见图 3。该节点为一 I/O 节点，主要负责发送数据。在该通信程序中设置邮箱 3 为发送邮箱，邮箱 3 一次只可发送 8 B 数据，该操作台至多可设置按键 48 个，把这 48 个开关量与主操作台节点地址 00FF H 组成 1 个数据帧（8 B），以广播地方式发送给各个子控制器，各子控制器接收到该数据帧后，对控制该子控制器的相应位进行判断，如相应位值均为 0，则认为控制该子控制器的按键未按下 如有一位或几位为 1，说明有键按下，该子控制器立即执行相应的动作，执行完毕后发送 8 B 的 FFFF H 给主操作台，主操作台接收到该数据后则认为子节点已接收到数据并已执行动作。

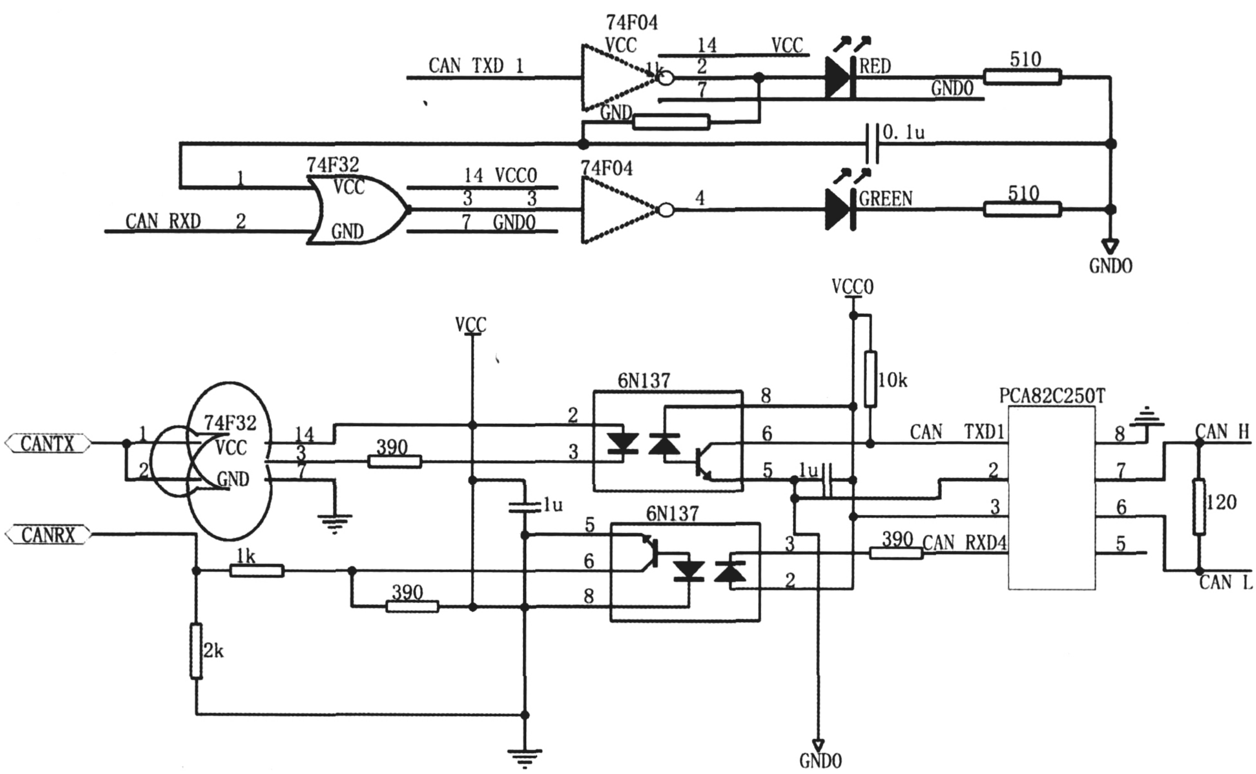

图 2 DSP 与 CAN 总线接口电路

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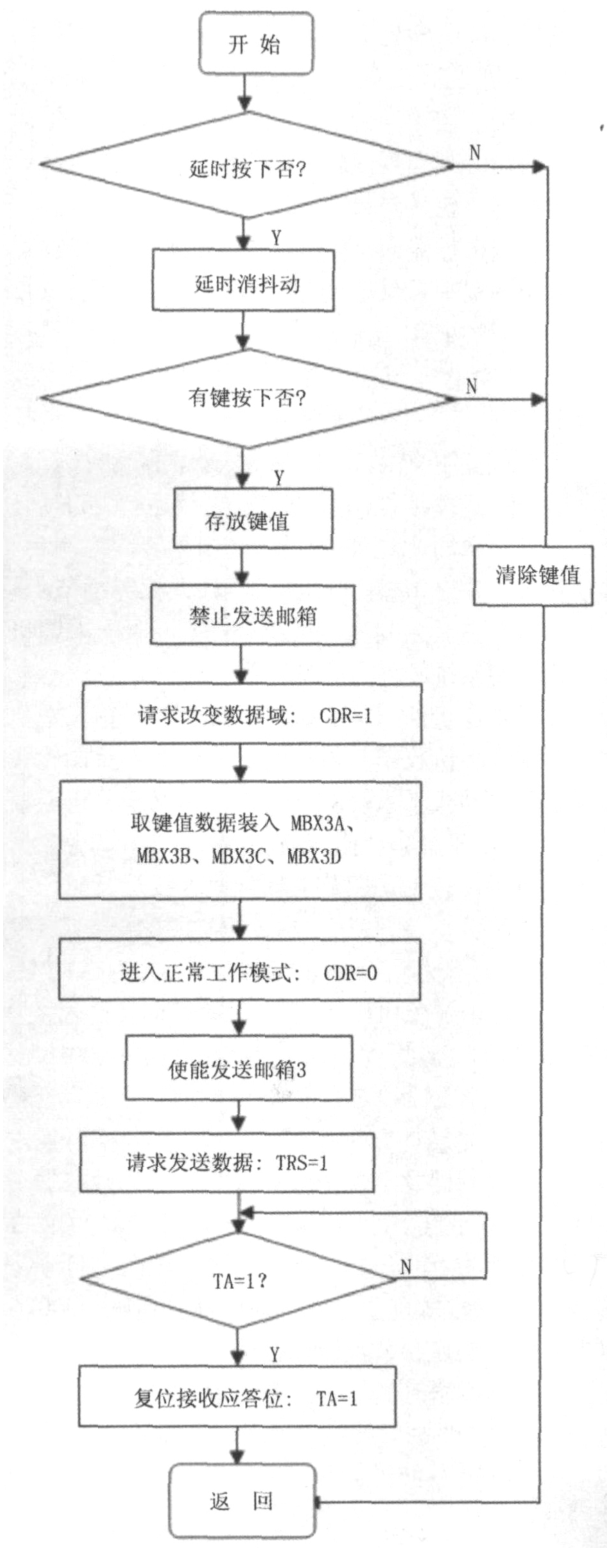

图 3 主操作台节点通信程序流程图

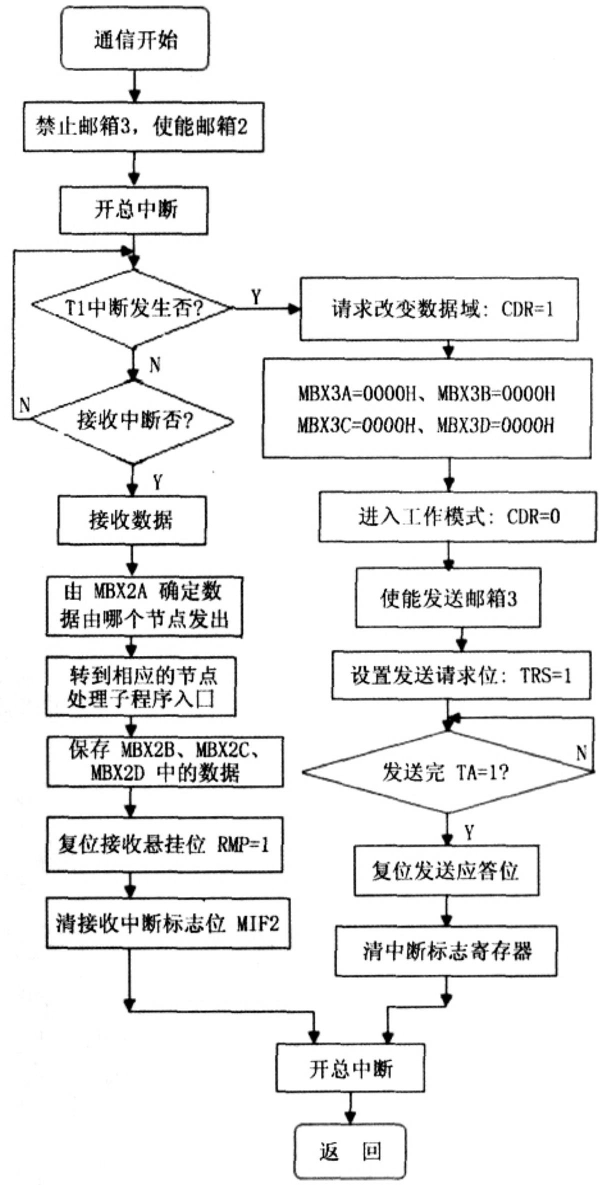

图 4 人机界面节点通信子程序流程图

⑵ 人机界面节点通信程序 流程图见图 4。该节点用于实时显示整机运行情况及故障信息等。它负责接收来自各子节点的数据。该通信程序位于主程序的定时器中断中，它定时以广播的方式向各子控制器发送命令，当子控制器接收到该数据帧后，立即把该子系统的当前运行状态及故障信息等组织成数据帧发送至人机界面节点，人机界面节点在接收中断时接收来自子节点的信息，当所有子节点数据发送完毕，通信程序跳出定时器中断，直到第 2 次中断来临，人机界面节点重新向各子节点发送命令，……如此循环，便实现了远程在线监视。

⑶ 子节点通信程序：该程序位于主程序的 CAN 接收中断中，无论是接收还是发送数据均在接收中断子程序中完成。通讯开始，子节点首先处于等待状态，等待接收来自主节点的数据。一旦接收到数据，则首先判断数据由主操作台节点还是由人机界面节点发出。如接收的数据帧其数据域为 8B 的

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00H,则数据由人机界面节点发出,子节点立即将相关信息装入邮箱,并即刻发送给人机界面节点,发送完后程序跳出接收中断,等待下一个命令的到来。如接收的数据帧其数据域 2 B 数据为 00FF H,则数据由主操作台节点发出,进而判断控制该子节点的按键是否按下,如按下,则执行相应动作 如未按下,程序立即跳出接收中断,等待下一个命令的到来。

3 试验结果及分析

通过试验研究,模拟现场施工环境,对基于 CAN 总线工程机械分布式控制系统的稳定性和可靠性进行验证。

本试验在包含 4 个节点的沥青混凝土摊铺机分布式模拟控制系统中进行,4 个节点分别为 :人机界面节点、主操作台节点、四轮转向控制台节点 (王红梅[4]设计,性能稳定,如图 5) 及自动找平控制台节点 (吴成富[1]设计,并已应用于实践,如图 6)。现在 4 节点全速运行:

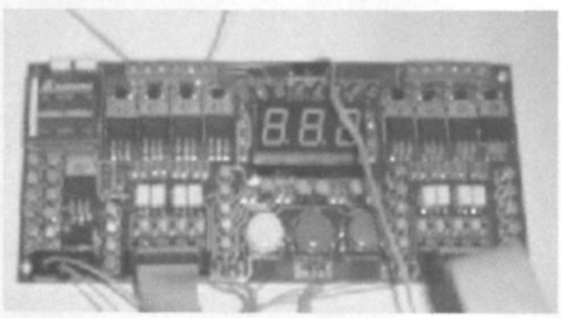

图 5 四轮转向控制器

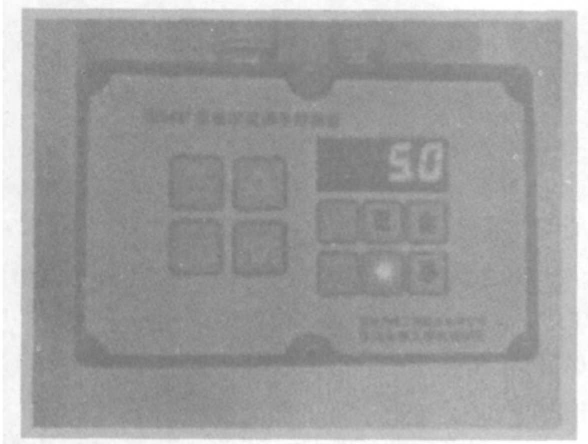

图 6 自动找平控制器

(1) 10 min 后不停改变四轮转向节点转向模式,随即人机界面节点显示屏信息随模式的变化而变化。

(2) 0.5 h 后不断旋转电位计 (模拟方向盘),人机节点显示屏不断更新方向盘转角值,超过转角范围后,显示屏显示故障并发出报警声,至故障排除。

(3) 按下主操作台节点全轮转向模式键,随即转动方向盘,观察到四轮转向系统转向模式由前轮转向转换为全轮转向,自动找平系统动作无变化。

(4) 现根据路面不平度,在主操作台节点设置找平系统的熨平板灵敏度为 0.1,人机界面节点及自动找平节点的 LED 显示屏立即显示 0.1。

(5) 初始设定摊铺机为手动找平模式,现按主操作台上"自动 / 手动"切换键,熨平板立即进入自动找平模式,相应人机界面节点显示屏显示"自动找平"。

该分布式模拟控制系统稳定连续运行 48 h 后,分析试验结果得出结论 :子节点 (四轮转向控制台、自动找平控制台) 能够与主控制器 (人机界面节点、主操作台节点) 之间进行数据通信,混凝土摊铺机分布式控制系统硬件及软件可靠。

在系统运行期间,通过任意改变各邮箱发送数据,再观察各接收邮箱数据的变化情况以及四轮转向系统和自动找平系统的动作执行情况来分析通信的可靠性,由于篇幅所限,现任意抽取 3 组试验数据如表 1 所示,表 1 是四节点均全速连续运行时任意抽取的 3 组数据。观察第二组数据 :主操作台节点发送邮箱初始数据为 8B 的 00H,现改为 3002H、1234H、0000H、0B50H,可发现四轮转向控制器及 2 号子节点接收到此数据后立即变为 8B 的 00H,而且四轮转向控制器 LCD 屏上转向模式由"前轮转向"变为"全轮转向"观察第三组数据 :同样可发现四轮转向控制器及 2 号子节点接收到操作台数据后立即变为 8B 的 00H,而且四轮转向控制器 LCD 屏上转向模式由"全轮转向"变为"斜行转向",且主操作台节点接收邮箱数据 0000H→FFFFH→0000H;以上表明主操作台节点以广播的方式向 2 个子节点发送数据,四轮转向控制器接收到数据后,判断需执行动作后,立即执行相应的动作,执行完后发送 8B 的 FFFFH 应答 如毋需执行动作,则忽略该数据继续别的动作。

4 结论

综上得出:子节点完全能够与主节点之间进行可靠的数据传输与通信,实现实时远程控制及监视。推广可得到:工程机械分布式控制系统可在多节点间进行通信,节点数≤110 个,通信距离≤150 m,通

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表 1　通信试验数据表

试验次数	节点邮箱		人机界面节点	主操作台节点	四轮转向控制台	自动找平控制台
1	接收邮箱	MBX2A	剧变后为 0000H	1111H→0000H	1111H→0000H	1111H→0000H
		MBX2B	剧变后为 0000H	1111H→0000H	1111H→0000H	1111H→0000H
		MBX2C	剧变后为 0000H	1111H→0000H	1111H→0000H	1111H→0000H
		MBX2D	剧变后为 0000H	1111H→0000H	1111H→0000H	1111H→0000H
	发送邮箱	MBX3A	0000H	0000H	3000H	0003H
		MBX3B	0000H	0000H	1112H	0020H
		MBX3C	0000H	0000H	42A0H	0005H
		MBX3D	0000H	0000H	0543H	0011H
2	接收邮箱	MBX2A	剧变后为 3002H	FFFFH→0000H	3002H→0000H	3002H→0000H
		MBX2B	剧变后为 1234H	FFFFH→0000H	1234H→0000H	1234H→0000H
		MBX2C	剧变后为 0000H	FFFFH→0000H	0000H	0000H
		MBX2D	剧变后为 0B50H	FFFFH→0000H	0B50H→0000H	0B50H→0000H
	发送邮箱	MBX3A	0000H	3002H	0000H	0000H
		MBX3B	0000H	1234H	0000H	0000H
		MBX3C	0000H	0000H	0000H	0000H
		MBX3D	0000H	0B50H	0000H	0000H
3	接收邮箱	MBX2A	剧变后为 0104H	FFFFH→0000H	0100H→0000H	0100H→0000H
		MBX2B	剧变后为 2345H	FFFFH→0000H	2345H→0000H	2345H→0000H
		MBX2C	剧变后为 0222H	FFFFH→0000H	0222H→0000H	0222H→0000H
		MBX2D	剧变后为 0456H	FFFFH→0000H	0456H→0000H	0456H→0000H
	发送邮箱	MBX3A	0000H	0104H	0100H	0100H
		MBX3B	0000H	2345H	0000H	0000H
		MBX3C	0000H	0222H	0000H	0000H
		MBX3D	0000H	0456H	0000H	0000H

信速率 500 kb/s。

基于 CAN 总线的工程机械分布式控制系统应用研究，为进一步开发工程机械分布式控制系统奠定了基础。

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that will influence the stability and safety in hoisting operation of the boom. Important outside vibration sources include effect of pavement, engine, and luffing movement of the boom during travel of the barrier- clearing vehicle, as well as load hoisting movement and boom slewing during hoisting operation. Among these, regularity of exciting frequency of pavement is more complicated and difficult to find out. In most cases, work speed of an engine, n, is from 600 to 8000 r/min, so engine speeds of greater influences (resonance) on boom are 1740r/min, 3950r/min (for totally retracted jib), 1520r/min and 2220r/min (for totally extending boom) that can be evaluated approximately. In practical operation, these speeds or near should be avoided as possible. Greater local distortion at luffing cylinder may occur so strength and rigidity should be enhanced at pivot location of the luffing cylinder during the design to ensure safety and stability of a barrier- clearing vehicle.

Keywords: ANSYS Heavy barrier- clearing vehicle
Boom Finite element Mode

Treatment for Material Sticking in Heating Drum for Regenerating Asphalt Aggregate

During reclaiming used asphalt pavement materials, the sticking heated aggregate will pile up between mixing vanes and drum wall seriously, which not only influences the material lifting capability of vanes but also results in material aging under long time heating. In order to reduce material piling thickness, approaching angle between vane and drum wall should be improved to make aggregate of unit mass have minimum contacting area with vane and drum wall. For the purpose, the contacting area between vane and drum wall is designed as an arc transition to avoid dead angle and the transitional arc radius is properly lengthened to reduce the arc height of piling material. Mixing drum vanes on model 2000 batch type asphalt concrete mixing equipment from Taian Yueshou Road Building Machinery Corporation are redesigned. Diameter of the drum is 2 m, speed ω is 0.52 rad/s, the transitional arc is designed as 0.35 m. Various grades of aggregates in reclaiming materials, three standards of AC- 25 Ⅰ, AC- 20 Ⅰ and AC- 16 Ⅰ, are all utilized and proportion of reclaiming material for regenerating material is set as 30% in the test. The test results show that the maximum thickness of piling material section is less than 0.05 m and the piling material can be completely removed by the aggregate.

Keywords: Asphalt concrete Hot regeneration
Drum design Treatment for sticking material

Causes Analysis for Poker Spindle Fracture of Model KCM130 Controllable Impact Spear and Its Optimal Design

Poker spindle is a key component in direction control mechanism for spear head of model KCM130 controllable impact spear. During the field test of a prototype, the direction control mechanism for spear head once failed due to poker spindle fracture. Aiming at this problem, loading conditions of the spear head under two different work postures are analyzed and dangerous work condition is determined as the loading condition when constructing a curved pole line. The distributing regularity of internal stress field of the poker spindle is mathematically simulated with finite element software and analysis results reveal that there are dangerous high stress sections inside the poker spindle. In association to macro profile and appearance characteristics of the poker spindle fracture, it is considered that main causes of the poker spindle fracture failure are concentrated stress and fatigue. Two optimal design schemes to reduce either internal stress concentration or stress level of the poker spindle are suggested. Compared and analyzed with original model by finite element method, the improvement designs are demonstrated rational and feasible.

Keywords: Controllable impact spear
Trenchless technology Poker shaft
Fracture failure Optimal design

Node Design of CAN Bus in Distributed Control System of Construction Machinery

The CAN field bus technology is applied to distributed control system of construction machinery for the first time and a structural model of the distributed control system is suggested. On the basis of that, concrete functions and structural characteristics of HCI nodes, main console nodes and other sub- nodes are described in details. With the purposes of simplifying hardware design and enhancing anti- interference function of the system, a high performance, 16- bit DSP TMS320LF2407 is used as a kernel element to realize the design of distributed control system for construction machinery. CAN controller embedded in TMS320LF2407 chip is used to construct CAN bus network. Hardware design for every node in the system is fulfilled and a photoelectric isolation method is employed on the hardware to protect CAN bus aganist interfering signals. Software design for each node is also fulfilled and a timing measurement method is employed on the software to ensure reliable data delivering in communication. Communication stability and reliability between nodes are verified through a simulation test. The results show that software and hardware in the distributed control system are stable and reliable, data delivering and communicating between main node and sub- nodes are reliable so that remote monitor on- line can be realized.

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Keywords: Distributed control system for construction machinery
CAN bus DSP Main node Sub-node

Important Points in Internal Combustion Forklift Design and Technical Development Trend

Nowadays, there is an increasingly competitive forklift market so that generation updating of forklift product technology has to be getting faster and faster. With the publication and implementing of various directives from EU as well as increasingly strong environment consciousness, current design of internal combustion forklift not only meets function requirements but also pays comprehensive attention on environment, humanization, safety, reliability, easy maintenance and etc. to realize humanism design concept. Taking the G series internal combustion counterweight type forklift as an example, design points and technical development trend of internal combustion forklifts are discussed.

Keywords: Internal combustion forklift
Environment protection Humanism
Safety Reliability Maintenance

Application of Induction Heating Equipment to the Heat Treatment Process of Semi-shaft in Rear Axle

Semi-shaft in rear axle is an important component for construction machinery to deliver torque and bears impact loads of bending and torsion. Its heat treatment will have a direct influence on the reliability of basic machine. Traditional strengthening processes for a semi-shaft are hardening plus tempering or induction quenching of medium frequency. The former presents inadequate surface strength but over-hardened core strength; but for the latter, due to the variable section of a semi-shaft and nonstandard equipment utilized, there should be a dedicated person to adjust electric parameters during continuously quenching procedure and the quenching quality is significantly influenced if improper operation or untimely parameter adjustment occurs. Induction heating quenching strengthening is conducted on the semi-shaft with IGBT full solid-state, medium frequency induction heating equipment. The heating evenness is increased due to the computer program control applied, which not only ensures the quenching quality but also can realize automated production.

Keywords: Construction machinery
Semi-shaft Induction heating Heat treatment

Using SOM Network Visualization to Diagnose Hydraulic System Failures

Because of the nonlinearity, complexity and variety of failure mechanism of a hydraulic system, it is very difficult to determine failure causes of a complicated hydraulic system. A new philosophy is presented for problem settlement of an unknown indefinite nonlinear system, using the excellent nonlinear mapping capability, self-learning adapting capability and concurrent information treatment capability of neural networks. A failure diagnosis method based on SOM neural network is described for hydraulic systems. SOM is a kind of important self-learning and training algorithm neural network. After training with the algorithm, a multiple dimension input space can be mapped into a 2D space and the failure symptoms can be automatically classified to obtain their relevant failure causes. At the same time, for the convenience of failure identification, U matrix diagram is utilized to visualize the simulation results of a neural network. With an example of outrigger hydraulic system of construction machinery, SOM network is used to simulate and visualize the results. The simulation results show that SOM network visualization method features identifying capability for failure modes and provides a new way for hydraulic system failure diagnosis.

Keywords: SOM network Visualization
Hydraulic system Failure diagnosis

Application of Logic Algebra to Failure Diagnosis of Hydraulic Systems

The servo hydraulic control systems in modern excavators are getting more and more complicated. There are multi-level crossing controls among each other so that once a failure occurs, it is difficult to clear their control relationships, analyze corresponding regularity between complicated failure symptoms and their causes and locate a failure and isolate it promptly. A code name is assigned for every hydraulic unit and valued as 0 or 1 according to its state (failed or normal) so that the control relationships of total hydraulic system can be equivalently demonstrated by "and", "or" and "not" logic expressions among hydraulic unit code names. The inference procedure in failure diagnosis can be replaced by logic addition and multiplication calculation among several "1" and "0". The inference process is simple and the test scheme is clear at a glance. A practical example verifies that the method provides an important way and measure for test scheme and troubleshooting of complicated servo hydraulic system and can also be transplanted into other mechanical, electro and hydraulic complex systems for failure test and diagnosis.

Keywords: Logic expression Hydraulic system
Failure diagnosis

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