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车辆脱轨安全限值的调整与改进建议

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摘要: 针对国家标准 GB5599- 85 评判车辆脱轨所存在的问题, 提出采用车轮抬升量作为车轮脱轨的直接判据。运用车辆- 轨道耦合动力学理论, 对我国主型货车 C_{62A} 分别以单轮对- 轨道耦合模型和整车- 轨道耦合模型为仿真计算对象, 研究了脱轨系数超限时间与车轮抬升量的关系。并对国家标准 GB5599- 85 中关于脱轨系数和轮重减载率的规定作了调整和改进, 建议将脱轨系数大于目标值 1.0 的持续作用时间小于 0.035 s 作为车辆脱轨的安全限值。

关键词: 车辆; 脱轨; 安全; 限值

中图分类号: U 211.5 **文献标识码**: A

随着货物列车提速及向长大/重载化方向发展, 长期依据的国家标准 GB5599- 85《铁道车辆动力学性能评定和试验鉴定规范》[1]已不能完全适应要求。脱轨安全性指标的规定存在一定缺陷, 有时甚至成为试验的束缚[2,3], 因此, 亟待对其进行适当调整和改进。

本文针对 GB5599- 85 标准, 运用车辆- 轨道耦合动力学理论[4]进行了详细的货车/轨道相互作用动力学仿真计算, 实现车轮爬轨和跳轨、脱轨仿真计算, 对脱轨安全指标的评判标准进行了分析和探讨。在此基础上, 广泛参考国内外有关标准的最新发展和实际运用经验, 提出了现行标准 GB5599- 85 中存在的问题及修订方案建议。

1 国内外最新脱轨判据

受日本 JNR 标准和国内多次线路试验的启发, 本文将车轮抬升量作为车辆脱轨的直接判据, 用车轮脱轨系数、轮重减载率超限时间分别代替脱轨系数和轮重减载率的安全限值, 并作为车轮脱轨的间接判据。车轮抬升量的定义见图 1。Z_{up} 为车轮抬升量, 定义为车轮名义接触点与钢轨顶面最高点之间的垂向距离; Z_1 为车轮爬升量; Z_2 为车轮跳动量。显然有 $Z_{up} = Z_1 + Z_2$。

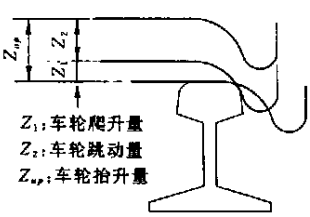

图 1 车轮抬升量的定义

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参考国家标准 GB5599- 85, 本文在计算中规定: 车轮脱轨系数安全限值为 $\lambda = 1.0$; 轮重减载率安全限值为 $\eta = 0.6$。定义: 脱轨系数超限(> 1.0)时间为 t_d; 轮重减载率超限(> 0.6)时间为 t_w。

2 仿真计算单轮对脱轨安全限值

轮对是机车车辆基础部件, 整车脱轨表现在轮对脱轨, 因此单轮对脱轨仿真研究是整车脱轨研究的基础。由于整车的运动状态和影响因素更为复杂, 较难进行脱轨机理和准则的研究, 因此, 将单轮对作为研究对象, 对于分析脱轨机理并构造合理的脱轨准则尤为重要。

为了使车轮能够脱轨, 人为地给轮对施加一横向力 F_y 和一绕 x 轴的力矩 M_x, 以帮助其爬上或跳上钢轨。在轮对脱轨仿真计算中, 考虑实际运行中的最不利情形是很重要的, 这里研究了爬升导致脱轨的条件, 并考虑现实条件[5]如下: 稳定轮重减载率为 40%～ 50%; 横向力为轴重的 0.3～ 0.4 倍; 最大冲角为 20m rad; 静态轮重为 35～ 105kN, 则有轮对的横向力 F_y 和绕 x 轴的力矩 M_x

$$\left.\begin{aligned} F_y &= 2P_0 \times 0.35 \\ M_x &= 2P_0 \times 0.4 \times 1.5 \times \sin\left(\frac{\pi}{T_s}t\right) \quad \left(0 \le t \le \frac{T_s}{2}\right) \end{aligned}\right\} \tag{1}$$

式中, t 为绕 x 轴的力矩 M_x 的作用时间; P_0 为静轮重; T_s 为力矩 M_x 的冲击时间宽度, M_x 为一半正弦冲击波。

在具体计算中, 首先将 F_y 施加在轮对上, 使脱轨侧车轮轮缘贴靠钢轨, 然后再对轮对施加 M_x 以使车轮爬上或跳上钢轨。

图 2 和图 3 为不同轴重和不同速度下的单轮对脱轨仿真计算结果, 分析如下:

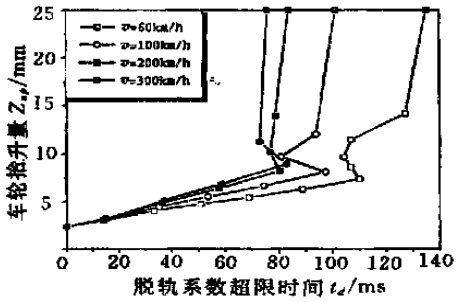


图 2　脱轨系数超限时间与车轮抬升量的关系(P_0 = 35kN)

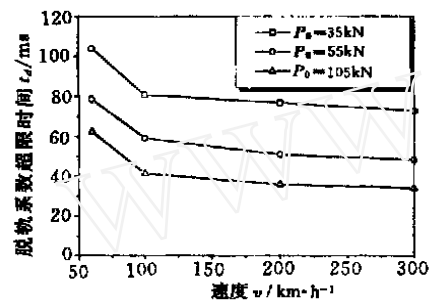


图 3　不同静轮重运行速度与脱轨系数超限时间的关系

(1) 随着作用在车轮上的力和力矩的冲击时间 T_s 增加, 脱轨系数超限时间 t_d 增大, 车轮的爬升量也随之增大。但当冲击时间 T_s 增加到一定时, 尽管车轮抬升量继续增大, 但脱轨系数超限时间反而有所减小, 成为短时间的脱轨, 车轮抬升量在极短时间内急速增大至轮缘高度值。在高速运行(200km/h 以上) 时, 更是如此。需要指出的是, 由于首先用横向力将车轮推至轮缘根部, 所以在脱轨系数作用时间为 0 时, 车轮已有抬升量约 2.35mm。图 2 表明了 P_0 = 35kN 下, 脱轨系数作用时间与车轮抬升量的关系。

(2) 从图 3 可以看到在相同静轮重下, 速度对车轮脱轨有一定的影响。当速度在 100km/h 以下时, 对车轮脱轨影响很大, 随着运行速度增加, 车轮越容易脱轨, 即所能允许的脱轨系数超限时间越小; 但当速度在 100km/h 以上时, 运行速度对车轮的脱轨影响作用则变得很小, 即所能允许的脱轨系数超限时间几乎相同。但从总的趋势来看, 运行速度越高, 车轮脱轨的危险性越大。

(3) 从图 3 可以看到在相同运行速度下, 静轮重对车轮脱轨影响很大。当 P_0 = 35kN 时, 所能允许的脱轨系数超限作用时间最大; 当 P_0 = 105kN 时, 所能允许的脱轨系数超限作用时间最小; 当 P_0 = 55kN 时, 所能允许的脱轨系数超限时间居中。显然, 在相同情况下, 车轮静轮重越小, 其脱轨的危险性越小, 即所能允许的脱轨系数超限时间越大。这一结果是基于爬轨脱轨而得出的, 与日本的单轮对仿真结果规律相符[5]。

(4) 从图 3 可以得到脱轨准则如下: 货物车辆的最大运行速度可以限制在 120km/h 以下, 其静轮重变化很大, 以最大静轮重考虑, 货物车辆的脱轨限值是脱轨系数超限时间小于 0.04s; 客车车辆的最大运行速度可以限制在 300km/h 以下, 其静轮重一般在 55kN 左右, 且变化不大, 以静轮重 55kN 计算, 客车车辆的脱轨限值是脱轨系数超限时间小于 0.05s; 如果综合客车和货车的速度和静轮重, 考虑静轮重 105kN 和速度 300km/h, 最后得到车辆的脱轨限值为脱轨系数超限时间小于 0.035s。显然该限值的裕量较大, 更偏于安全。

图 4 和图 5 给出了脱轨过程中, 车轮抬升量和轮轨垂向力的变化过程。其计算条件为静轮重 35kN, 力矩 M_x 冲击时间 T_S = 0.15s, 轮对冲角 20m rad。从图 4 和图 5 可以看到, 在整个脱轨过程中轮轨垂向力最小为 20kN, 说明脱轨过程轮与轨始终接触而未产生跳动, 故可将此脱轨过程定义为爬轨脱轨。

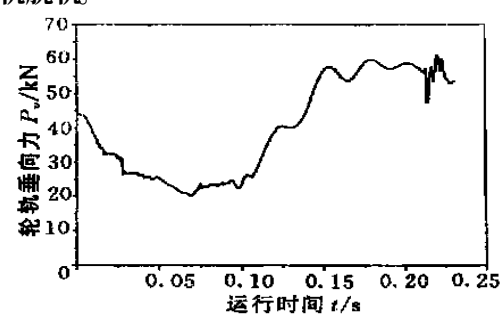


图 4　轮轨垂向力

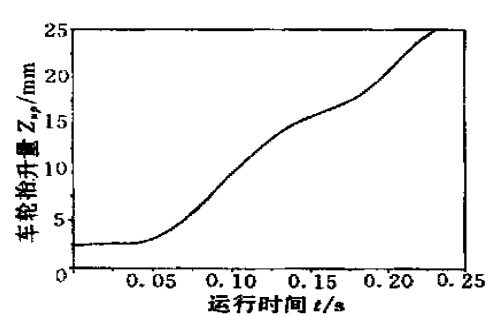


图 5　车轮抬升量

多次线路试验表明, 我国主型货车 C_{62A} 的脱轨原因是由于在 70km/h 以上速度运行时所出现的强烈蛇行运动所致。车辆一旦失稳, 车轮的横向冲击和轮重减载将变得更大, 车轮将产生跳轨, 而

且线路试验也表明了轮重减载率达到最大值 1.0 的情形时有出现。另外，在较大的轨道不平顺的作用下，也很容易发生轮重减载至零，出现轮轨脱离的情形。所以有必要针对 C_{62A} 的脱轨特点来研究其跳轨脱轨的安全限值。在此，应用轮重减载率超过目标值 0.6 的持续作用时间 t_w 来加以衡量。为了计算跳轨脱轨，不考虑爬轨和横向力的作用，仅考虑 M_x，为了使轮载减到 0，需要加大该力矩作用。故设定

$$\left.\begin{aligned} F_y &= 0 \\ M_x &= 2P_0 \times 0.4 \times 1.5k\sin\left(\frac{\pi}{T_s}t\right) \quad \left(0 \le t \le \frac{T_s}{2}\right) \end{aligned}\right\} \tag{2}$$

式中，k 为系数，为留有安全裕度，取 $k = 1.5$。

表 1 为静轮重 $P_0 = 35$kN 时，轮重减载率超

表 1　轮重减载率大于 0.6、脱轨系数大于 1.0 的时间与车轮抬升量的关系（$k = 1.5$, $P_0 = 35$kN）

力矩冲击时间 T_S (s)	轮重减载率大于 0.6 的时间 (m s)	脱轨系数大于 1.0 的时间 (m s)	车轮抬升量 (mm)
0.02	32.62	30.82	3.89
0.04	56.42	53.73	8.32
0.06	76.81	72.42	12.91
0.08	94.82	89.71	17.01
0.10	111.22	97.32	20.72
0.12	126.13	110.01	24.23
0.14	93.41	72.72	25.00

限时间、脱轨系数超限时间与车轮抬升量的关系。

图 6 和图 7 为 $k = 1.5$、静轮重为 35kN、轮对冲角为 20m rad、力矩冲击时间为 $T_s = 0.14$s 的条件下，车轮的跳轨脱轨过程。

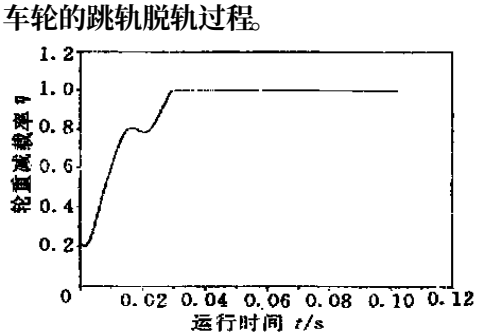


图 6　轮重减载率

从表 1 中不难发现，轮重减载率的作用时间与脱轨系数超限作用时间基本相当。

图 7 表示了 $k = 1.5$ 时，不同静轮重脱轨系数超限时间与车轮抬升量的关系。

3　主型货车 C_{62A} 整车脱轨仿真分析

单轮对脱轨仿真对脱轨机理分析和脱轨准则

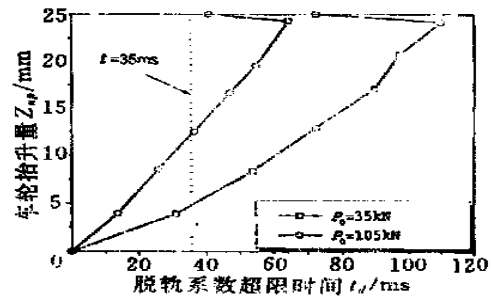


图 7　脱轨系数超限时间与车轮抬升量的关系

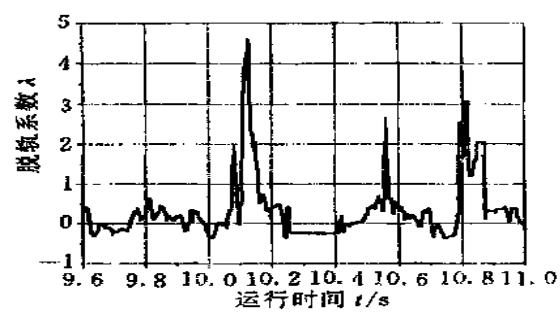
的研究很重要，为了验证由单轮对脱轨仿真得到的脱轨准则是否合适，必须建立整车模型以进行整车脱轨仿真研究。

我国近几年列车提速以来，货物列车在直线段的脱轨事故逐渐增多，严重影响了运输安全。通过多次线路试验[2,3]，查明了导致货物列车脱轨的主要原因是由于货车在直线上运行所产生的蛇行运动。由于 C_{62A} 空车更容易产生蛇行运动，故在整车仿真计算中，选择 C_{62A} 空车进行脱轨仿真计算。

为了模拟实际的运行情况，计算在轨道随机不平顺激扰下，C_{62A} 空车以不同的运行速度在直线轨道上运行时的脱轨安全性，其中轨道谱为我国三大重载、提速干线谱[6]。表 2 为不同速度运行时，各轮对的脱轨安全性指标的变化情况。结合表 2 的计算结果，分析如下：

(1) 造成 C_{62A} 货车直线脱轨的主要原因是其空车的稳定性较差，一旦产生了强烈的蛇行运动，车轮将相对钢轨产生很大的横向位移，并且来回碰撞钢轨，从而产生脱轨。车辆运行速度越高，蛇行运动越剧烈，越容易脱轨。

(2) 在车辆蛇行失稳诱发的脱轨中，由于轮对相对钢轨有很大的横向冲击速度，整个脱轨过程以爬轨和跳轨并存。见图 8、图 9，轮对 Ⅰ 左轮表现出爬轨 - 跳轨 - 爬轨 - 跳轨的交替运动形式，因此，车辆蛇行运行失稳后，其脱轨形式较为复杂。



(轮轨脱离后，脱轨系数为上时刻值)

图 8　脱轨侧车轮脱轨系数

表 2　C_{62A} 货车运行速度对其脱轨安全性的影响

v (km/h)	轮位	脱轨系数 λ		轮重减载率 η		脱轨系数超限时间 t_d (m s)		车轮抬升量 Z_{up} (mm)	
		左	右	左	右	左	右	左	右
60	Ⅰ	0.429	0.433	0.873	0.779	0.000	0.000	1.235	0.792
	Ⅱ	0.476	0.466	0.771	0.703	0.000	0.000	0.532	0.688
	Ⅲ	0.415	0.497	0.618	0.687	0.000	0.000	0.737	0.627
	Ⅳ	0.368	0.417	0.699	0.635	0.000	0.000	0.546	0.623
80	Ⅰ	1.042	1.821	1.000	1.000	86.96	28.94	0.933	-0.676
	Ⅱ	1.229	1.113	1.000	1.000	13.22	34.17	-0.801	-0.708
	Ⅲ	1.014	0.786	1.000	1.000	3.318	40.67	-0.239	0.301
	Ⅳ	0.899	0.694	0.838	1.000	0.000	19.75	2.405	0.054
90	Ⅰ	2.551	2.130	1.000	1.000	59.96	63.10	11.52	11.40
	Ⅱ	2.042	2.041	1.000	1.000	51.46	57.25	10.20	9.244
	Ⅲ	1.932	2.156	1.000	1.000	59.08	131.5	13.30	9.881
	Ⅳ	1.931	1.790	1.000	1.000	73.21	73.59	15.13	13.49
100	Ⅰ	5.812	3.914	1.000	1.000	58.97	61.03	22.63	15.62
	Ⅱ	3.467	4.084	1.000	1.000	67.47	52.89	20.52	16.74
	Ⅲ	4.762	3.914	1.000	1.000	79.48	50.93	11.97	12.80
	Ⅳ	3.332	6.988	1.000	1.000	77.12	77.83	15.82	12.40

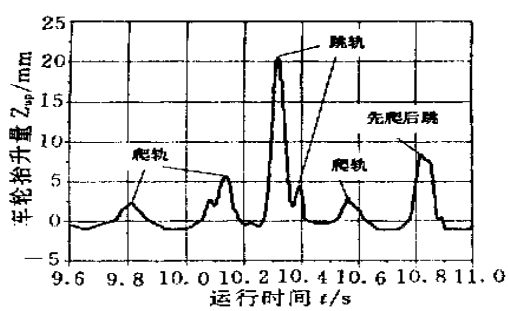


图 9　脱轨侧车轮抬升量

从表 2 看出, 脱轨系数大于 1.0 的作用时间变化范围很大, 如将其限制在 35m s 内, 则各种速度下车轮抬升量均小于轮缘高度, 表明车辆没有任何脱轨危险。显然, 由单轮对脱轨仿真得到的脱轨安全限度是安全的。

4　结论

车辆的脱轨过程是一个非常复杂的轮轨相互作用的力学行为, 因素影响多, 难于用一个统一的标准来进行评判。我国国家标准 GB 5599- 85 对车辆脱轨的判断显然偏于保守。为了减少误判和避免漏判, 通过对单轮对和整车脱轨的仿真计算, 脱轨系数可以大于目标值 1.0, 轮轨可以出现短时间脱离现象, 即轮重减载率可以达到最大值 1.0。脱轨仿真计算结果表明, 只要将脱轨系数超限的持续作用时间和轮重减载率超限的持续作用时间限制在 35m s 以内, 则可保证车辆运行的脱轨安全性。因此, 建议在调整后的脱轨系数和轮重减载率的评判规范中, 增加将脱轨系数超限和轮重减载率超限的持续作用时间均限制在 35m s 以内这一标准。

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MAIN TOPICS, ABSTRACTS & KEYWORDS

Study on the Chisel Anti-Rebound Mechanism of Hydraulic Impactor ZHANG Xin (Zhejiang University, Hangzhou, China) CHEN Zichen SUN Guohui p 631-633

Abstract: In order to develop a mechatronical intelligence breaking hydraulic impactor, this paper presents a chisel anti-rebound mechanism, which could identify automatically the physical characteristics of working medium. After establishing the nonlinear mathematical model of the mechanism, a dynamic simulation has been conducted, the relationship between the chisel rebound speed and the performance of the anti-rebound mechanism has been studied systematically. So the regularity about the mechanism motion has been found out. This paper describes a experimental device of the chisel anti-rebound of hydraulic impactor. According to the data collected from the experiments, the simulation results were in good agreement with the experimental ones. A good way that realized the hydraulic impactor intelligent control has been found out.

Key words: chisel anti-rebound; dynamic simulation; experiment; hydraulic impactor; intelligence control

Dynamic Analysis and Design Criteria of Vibration Stability for Large Hydro-generator Units HAN Guoming (Zhengzhou Research Institute of Mechanical Engineering, Zhengzhou, China) ZHANG Xinzhi LIU Baoguo p 634-636

Abstract: Problems of dynamics in structural design for large hydro-generator units are discussed in this paper. For the vertical shaft units, methods of modeling and dynamic response estimation, distinguished from traditional methods in rotor dynamics, are presented. Evaluation criteria in design stage for vibration stability of the units are recommended. Finally, an example of engineering application is given.

Key words: hydro-generator units; stability; design criteria

Mobile Robot's Trajectory Following Based on Color Vision and Fuzzy Control ZHANG Minglu (Hebei University of Technology, Tianjin, China) GUANG Boqing DING Chengjun p 636-639

Abstract: In this paper, the trajectory is detected by using color information in the images. It simplifies feature extraction in images and improves the robustness of trajectory extracting. Fuzzy logic control strategy avoids the process of complex modeling in traditional control and enables the trajectory following system fit for the non-linearity and uncertainty of the environment. Moreover, the factors effecting on the system are analyzed in this paper and the lag of the vision system is corrected. Now, this trajectory following method has been successfully applied to HEBUT-1 intelligent mobile robot.

Key words: mobile robot; trajectory following; color vision; fuzzy control

Seam Recognition and Seam Tracking Based on Distribution of Welding Temperature Field XIANG An (Nanchang University, Nanchang, China) PAN Jiluan ZHANG Hua JIA Jianping PAN Junmin p 640-643

Abstract: In this paper, a method of seam recognition and a fuzzy control system for seam tracking is proposed. Based on the distribution of welding temperature field, the error of seam is obtained, a self-adjusting fuzzy controller is used to seam tracking. Experiments and real production show that seam is recognized accurately and the control system is reliable and stable.

Key words: seam tracking; welding temperature field; fuzzy control; MIG/MAG; submerged arc welding

Study on GCr15 Friction Behavior before and after the Transition from Fretting to Reciprocating Sliding Wear CHEN Guangxiong (Southwest Jiaotong University, Chengdu, China) ZHOU Zhongrong LI Hong p 643-645

Abstract: An experimental study on the transition between fretting and reciprocating sliding wear has been carried out using a AISI 52100 steel ball of 60mm diameter rubbed against a flat specimen made from the same steel under 300 N normal load. Wear coefficient, coefficient of friction and wear mark morphology were analyzed and debris observation was made. The results show that in addition to wear coefficient friction coefficient and wear mark morphology also have to some extent changes before and after the transition. A transition probably occurs between 70 μm and 100 μm under the present conditions.

Key words: fretting wear; reciprocating sliding wear; transition; wear coefficient

Suggestions of Adjustment and Improvement on Vehicle Derailment Safety Limit Value CHEN Guo (Nanjing University of Aeronautics and Astranautics, Nanjing, China) ZHAI Wanming ZUO Hongfu p 646-649

Abstract: In this paper, aiming at the serious problems that exist in the Chinese current national standard, GB5599-85, the newest research results at home and abroad are consulted, the wheel vertical rise height is applied to be regard as direct distinguish evidence. The vehicle-track coupling dynamics theory is applied, aiming to Chinese leading type freight vehicle C62A, the single wheelset/track coupling model and the full-scale vehicle/track coupling model are acted as the objects of numerical simulation. The relation between the duration that derailment coefficient exceeds safety limit and wheel vertical rise height is researched in detail. Finally, the great adjustment and improvement advice on

derailment coefficient and wheel weight decreasing rate in Chinese standard GB5599-85, is made, and it is suggested that the duration of derailment coefficient exceeding safety limit value should be shorter than 0.035s.

Key words: vehicle derailment safety limit value

Experimental Research on the ER (Electro-Rheological) Damper for Milling Machine Vibration Control
WANG Maohua (Jilin University, Changchun, China) ZHANG Yongliang YU Junyi p. 650-652

Abstract: The application of an ER damper for milling machine vibration control is studied by some experiments. It is observed that the stiffness and damping of ER damper are enhanced with the increas, of electric field density and the vibratory amplitude of main vibration system is reduced by raising the electric field density. The experimental results show that ER damper characterized by obvious vibration control effects and simple structure. As long as the electrical field density selected is appropriate, the vibratory amplitude of milling cutter shaft system can be controlled.

Key words: electro-rheological fluid (ERF) ER damper vibration control damping stiffness

On Basic Problems of Designing a Rotating-Bending Fatigue Cutting Machine
GONG Jun (Gansu University of Technology, Lanzhou, China) HOU Yunfeng WEI Qingtong LANG Fuyuan p. 652-653

Abstract: Metal bar would be fractured under the rotating-bending fatigue alternating stress. Based on this theory a rotating-bending fatigue-cutting machine was invented and applied in manufacturing industry. So it's a kind of machine which takes advantage of fatigue-fracture. The achievements and advances in recent years are introduced in this paper, including effect of notch parameter on fatigue-fracture, the main factors effecting cutting efficiency and fracture quality, development and application of fatigue-cutting machine.

Key words: rotating-bending fatigue fatigue-cutting machine notch parameter fatigue-cutting

Research on Agile Manufacturing Execution System in Shop Floor
RAO Yunqing (Huazhong University of Science & Technology, Wuhan, China) LIU Shiping LI Shuxia LI Peigen p. 654-656

Abstract: The agility of production management and operation in shop floor makes an important contribution to the computer integrated manufacturing (CIMS) and agile manufacturing strategies, and manufacturing execution system (MES) is the basic approach to reach the agility of production management in shop floor. The agility of MES embodies the rapid response on its performance and quick reconfiguration of its structure. The multi-agent system (MAS) theory and method are applied to develop the MES framework, and an unified structure form of each agent, together with the cooperative mechanism between each other are designed in this paper. Sequentially, an agile MES prototype is developed, and its work flow is introduced briefly.

Key words: MES (manufacturing execution system) production management in shop floor agility MAS (multi-agent system)

A Practical Algorithm for the Resource Balancing Problems in Large-Piece OKP Mode
JIANG Sijie (Harbin Institute of Technology, Harbin, China) XU Xiaofei p. 657-659

Abstract: Large-piece OKP is one of the typical production modes of large enterprise groups. One of the main characteristics of this kind production mode is that the utilization of key or bottleneck resources determines the productivity. In China, enterprises of Large-piece OKP type play a relatively important role whose production planning and control (PPC) are not only complicated but no shared pratical mode as well. Based on the review over all kinds of PPC modes as well as combined with the 863/CIMS key demonstrative project, this paper firstly presents a practical production mode combining CPM with MRP, and then, puts forward a practical algorithm to solve the resource balancing problems with this mode.

Key words: large-piece OKP CPM MRP heuristic algorithm

Modeling Manufacturing System Virtual Environment Using Multi Agent
ZHAO Ji (Tsinghua University, Beijing, China) XIAO Tianyuan ZHU Mingquan HAN Xiangli p. 660-662

Abstract: Modeling and simulation is the kernel of virtual manufacturing system. For coping with the simulation requirements of virtual manufacturing environment, a multi-Agent modeling method is proposed. For specific production line—FMS, virtual model of each machine is well defined using agent, so the virtual environment can be seen as a society of agents, which are represented by software units encapsulating logic inference and kernel computation. The manufacturing activities in virtual environment are described as the collaboration and coordination among the agents, and the definition of agent and its realization method are given.

Key words: manufacturing system virtual environment modeling Agent

The Study of Reconfigurable Manufacturing Executive System Based on Holon
ZHU Jianjiang (Nanjing University of Aeronautics and Astranautics, Nanjing, China) DAI Yong WANG Ningsheng p. 663-665

Abstract: This paper presents the Holon architecture, communication mechanism and the cooperating mode. Based on analyzing the feature of enterprise activities, using object-oriented method, the Holon model of MES is defined, and the distributed network computing model of MES control software is given. Three kinds of reconfiguration mode are also presented, and through a reconfigurable example about inventory management, the feasibility of the reconfiguration method presented in this paper is proved.

Key words: Holon reconfigurability distributed MES CORBA

Research on Forecasting and Control of FMS Machining Dimension and Process Capability
ZHANG Libin (Jilin University, Changchun, China) JIA Yazhou TAO Liguo p. 665-668

Abstract: On-line modeling and forecasting for machining dimension of FMS is studied and carried out by applying time series analysis theory. Combining the forecasting of machining dimension with that of process capability in a machining process, principle and method of feed-back compensative control is proposed in the paper. After statistical analysis of obtained machining data series in FMS with feed-back compensative control, the results are feasible.

Key words: time series forecasting process capability feed-back compensative-control

Research on Enterprise Dynamic Collaboration's Agility