NICHOLAS P. CHIRONIS **NEIL SCLATER** MECHANISMS & MECHANICA DEVICES SOURCEBOOK

SECOND EDITION

New York San Francisco Washington, D. C. Auckland Bogotá Caracas Lisbon London Madrid Mexico City Milan Montreal New Delhi San Juan Singapore Sydney Tokyo Toronto

McGraw-Hill

CONTENTS

×.

ΥI
~

v

PREFACE		xi
CHAPTER 1	PARTS-HANDLING MECHANISMS	1
	Orienting parts for assembly	2
	Mechanisms that sort, feed, or weigh	8
	Cutting mechanisms	12
	Feeder mechanisms	15
 	Seven basic parts selectors	19
	Twelve designs for feeding, sorting, and counting mechanisms	20
	Parts-handling mechanisms	26
	Innovative automatic feed mechanisms	28
	Linkages for transport mechanisms	30
	Conveyor systems for production machines	32
	Traversing mechanisms for winding machines	36
	How to collect and stack die stampings	38
	Vacuum pickup positions pills	39
	Machine applies labels from stacks or rollers	39
	Detectors for automatic die operation	40
	Stepping-off tube lengths	46
	How labeling machines work	47
	Adhesive applications for high-speed machines	50
	Automatic stopping mechanisms for faulty machine operation	56
	Electrical automatic stopping mechanisms	62
	Automatic safety mechanisms for operating machines	64
	New mechanism stops spin	66
	Six-degree-of-freedom parallel minimanipulator	68
	Self-reconfigurable, two-arm manipulator with bracing	69
CHAPTER 2	RECIPROCATING AND GENERAL-PURPOSE MECHANISMS	71
	Gears and eccentric disk combine in quick indexing	72
	Timing belt, four-bar linkage team up for smooth indexing	73
	Modified ratchet drive	74
	Odd shapes in planetary give smooth stop and go	75
	Cycloid gear mechanism controls stroke of pump	77
	Converting rotary-to-linear motion	78
	New star wheels challenge geneva drives for indexing	78
	Geneva mechanisms	81
	Modified geneva drives	84
	Indexing and intermittent mechanisms	86
	Rotary-to-reciprocating motion and dwell mechanisms	94
	Friction devices for intermittent rotary motion	100
	No teeth on these ratchets	102

	Escapement mechanisms	103	
	Cam-controlled planetary gear system	106	
CHAPTER 3.	SPECIAL-PURPOSE MECHANISMS	107	
	Unique linkage produces precise straight-line motion	108	
	Linkage arrangements for engine valves	110	
	Stroke of oscillating, rotating shaft is varied while turning	111	
	Twelve expanding and contracting devices	112	
	Five linkages for straight-line motion	114	
	Linkage ratios for straight-line mecahinisms	116	
	Five cardan-gear mechanisms	118	
	I n ways to change straight-line direction	120	
	Nine more ways to change straight-line direction	122	
	Linkages for multiplying short motions	124	
	Converting impulses to mechanical movements	120	
	Parallel-link mechanisms	131	
	Stroke multiplier	131	
	Force and stroke multipliers	133	
	Stroke-amplifying mechanisms	135	
	Adjustable-stroke mechanisms	136	
	Adjustable-output mechanisms	137	
	Reversing mechanisms	139	
	Mechanical linkage varies compression in radial engine	140	
	Computing mechanisms	141	
	Eighteen variations of the differential mechanism	145	
	Function mechanisms	147	
	Space mechanisms	149	
	Three-dimensional drives	151	
	Piezoelectric motor in robot finger joint	156	
	Tool-changing mechanism for robot	157	
	Inchworm actuator	158	
	"Mighty worm" piezoelectric actuator	159	
	Hazardous-materials robot	159	
	Basic industrial robot mechanisms	161	
CHAPTER 4.	SPRING, BELLOW, FLEXURE, SCREW, AND BALL DEVICES	167	
	A simple roller-band device challenges established mechanisms	168	
	Seven applications for the constant-force spring	172	
	Flat springs in mechanisms	173	
	Pop-up springs get new backbone	175	
	Twelve ways to put springs to work	176	
	Overriding spring mechanisms for low-torque drives	178	
	Spring motors and typical associated mechanisms	180	
	Flexures accurately support pivoting mechanisms and instruments	182	
	The store devices—for economic action	104	
	raut bands and leadscrew provide accurate rotary motion	100	

Air spring mechanisms	186
Obtaining variable rates from springs	188
Belleville springs	189
Spring and linkage arrangements for vibration control	190
Twenty screw devices	191
Ten ways to employ screw mechanisms	194
Seven special screw arrangements	195
Fourteen adjusting devices	196
Ball-bearing screws convert rotary-to-linear motion	197
Conversion of rotary-to-linear motion	199
Three-point gear/leadscrew positioning	200

CHAPTER 5. CAM, TOGGLE, CHAIN, AND BELT MECHANISMS

	Generating cam curves	202
	Fifteen ideas for cam mechanisms	208
	Special-function cams	210
	Adjustable-dwell cams	211
	Cam drives for machine tools	211
	Toggle linkage applications in different mechanisms	212
	Sixteen latch, toggle, and trigger devices	214
	Six snap-action mechanisms	216
	Eight snap-action devices	218
	Applications of the differential winch to control systems	220
	Six applications for capstan-type power amplifiers	222
	Guide to variable-speed belt and chain drives	225
	Centrifugal clutch varies output of belt transmission	228
	Getting in step with hybrid belts	229
	Change center distance without affecting speed ratio	233
	Motor mount pivots for controlled tension	233
	Mechanisms for reducing pulsations in chain drives	234
	Smoother drive without gears	236
CHAPTER 6.	GEARED SYSTEMS AND VARIABLE-SPEED MECHANISMS	237
	Nutating-plate drive	238
	Cone drive needs no gears or pulleys	238
	Guide to variable-speed mechanical drives	239
	Variable-speed drives	248
	Ratchet and inertia variable-speed drives	250
	Precision ball bearings replace gears in tiny speed reducers	252
	Multifunction flywheel smoothes friction in tape cassette drive	253
	Controlled differential drives	254
	Twin-motor planetary gears provide safety plus dual-speed	255
	Harmonic-drive speed reducers	255
	Flexible face-gears make efficient high-reduction drives	258
	Compact rotary sequencer	259

Planetary gear systems

260

Noncircular gears	267	
How to prevent reverse rotation	271	
Gear-shift arrangements	272	
Shifting mechanisms for gears and clutches	274	
Fine-focus adjustments	276	
Ratchet-tooth speed-change drive	277	
Applications for Twinworm	277	
Compliant gearing for redundant torque drive	279	
Lighter, more efficient helicopter transmissions	280	
Worm gear with hydrostatic engagement	280	
Straddle design of spiral beval and hypoid gears	282	
CHAPTER 7. COUPLING, CLUTCHING, AND BRAKING DEVICES	283	
Novel linkage that can couple offset shafts simplifies		
the design of a variety of products	284	
Disk-and-link coupling simplifies transmissions	286	
Intertwining links produce true constant-motion universal	287	
Interlocking space-frames flex as they transmit shaft torque	288	
Off-center pins cancel misalignment of shafts	290	
Hinged links and torsion bushings give drives a soft start	291	
Universal joint relays power 45 degree at constant speeds	292	
Flexible shafts take on more jobs	293	
Spring-wrapped slip clutches	296	
Controlled-slip concept adds new uses for spring clutches	298	
Spring bands grip tightly to drive overrunning clutch	299	
Slip and bidirectional clutches combine to control torque	300	
Clutch/brake system makes tape recorder foolproof	301	
Walking pressure plate delivers constant torque	302	
Conical-rotor motor provides instant clutching or braking	303	
Fast-reversal reel drive	303	
Seven overrunning clutches	304	
Spring loaded pins and sprags in one-way clutch	305	
One-way output from speed reducers	306	
Novel one-way drives	307	
Construction details of overriding clutches	309	
Ten ways to apply overrunning clutches	311	
Applications of sprag-type clutches	313	
Small mechanical clutches for precise service	315	
Mechanisms for station clutches	317	
Twelve applications of electromagnetic clutches and brakes	319	
Ten universal shaft-couplings	321	
Typical methods of coupling rotating shafts	323	
Linkages for bank clutches and brakes	327	
Special coupling mechanisms	328	
Special-link coupling mechanisms	329	
Trip roller clutch	330	
Geared electromechanical rotary joint	331	

CHAPTER 8.	TORQUE-LIMITING, TENSIONING, AND GOVERNING DEVICES	333
	Caliper brakes help maintain proper tension in press feed	334
	Sensors aid clutch/brakes	334
	Warning system prevents overloading of boom	335
	Constant watch on cable television	335
	Torque-limiters protect light-duty drives	336
	Ways to prevent overloading	337
	Seven ways to limit shaft rotation	340
	Mechanical systems for controlling tension and speed	342
	Drives for controlling tension	346
	Cutoff prevents overloading of hoist	349
	Ball-type transmission is self-governing	349
	Mechanical, geared, and cammed limit switches	350
	Limit switches in machinery mechanisms	352
	Mechanical devices for automatically governing speed	356
	Centrifugal, pneumatic, hydraulic, and electric governors	358
	Speed control for small mechanisms	360
	Mechanical timers	361
	Floating-pinion torque splitter	362

CHAPTER 9. PNEUMATIC AND HYDRAULIC MACHINE AND MECHANISM CONTROL

363

Providing freedom to move six ways	364
Hydrostatic drive teams with swash plate in all-terrain vehicle	365
Mechanisms actuated by pneumatic or hydraulic cylinders	366
More applications of fluid power	368
Self-powered hatch cover	369
Hydraulic dumpers and loaders	369
Rotary-pump mechanisms	370
Foot-controlled braking system	372
Team of linkages actuates steering in 300 horsepower diesel tractor	372
Fifteen jobs for pneumatic power	373
Ten ways to use metal diaphragms and capsules	374
Differential transformer sensing devices	376
High-speed counters	378
Permanent magnet mechanisms	379
Electrically driven hammer mechanisms	382
Thermostatic mechanisms	384
Temperature-regulating mechanisms	388
Photoelectric controls	390
Liquid level indicators and controllers	392
Instant muscle with pyrotechnic power	394
•• • • • • • • • • • • • • • • • • • •	

CHAPTER 10. FASTENING, LATCHING, CLAMPING, AND CHUCKING DEVICES 397

Remotely controlled latch

398

New grapple frees loads automatically39Quick-release lock pin has foolproof ball device40Automatic brake locks hoist when driving torque ceases40Lift-tong mechanism firmly grips objects40Perpendicular-force latch40Quick-release mechanisms40Ring springs clamp platform elevator into position40Cammed jaws in hydraulic cylinder grip sheets40Quick-acting clamps for machines and fixtures40Friction clamping devices and principles of design40Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Actuator exerts tensile or compressive axial load41Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	 99 00 00 01 01 02 03 03 04 06 08 10 10 11 12
Quick-release lock pin has foolproof ball device44Automatic brake locks hoist when driving torque ceases46Lift-tong mechanism firmly grips objects44Perpendicular-force latch46Quick-release mechanisms46Ring springs clamp platform elevator into position46Cammed jaws in hydraulic cylinder grip sheets46Quick-acting clamps for machines and fixtures46Friction clamping devices and principles of design46Detent designs for stopping mechanical movements46Spring-loaded chucks and holding fixtures47Actuator exerts tensile or compressive axial load47Gripping system for mechanical testing of composites47Probe-and-socket fasteners for robotic assembly47	00 00 01 01 02 03 03 03 04 06 08 10 10 11
Automatic brake locks hoist when driving torque ceases40Lift-tong mechanism firmly grips objects40Perpendicular-force latch40Quick-release mechanisms40Ring springs clamp platform elevator into position40Cammed jaws in hydraulic cylinder grip sheets40Quick-acting clamps for machines and fixtures40Friction clamping devices and principles of design40Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Actuator exerts tensile or compressive axial load41Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	00 01 01 02 03 03 04 06 08 10 10 11
Lift-tong mechanism firmly grips objects44Perpendicular-force latch44Quick-release mechanisms44Ring springs clamp platform elevator into position44Cammed jaws in hydraulic cylinder grip sheets44Quick-acting clamps for machines and fixtures44Friction clamping devices and principles of design44Detent designs for stopping mechanical movements44Spring-loaded chucks and holding fixtures44Short in-line turnbuckle44Actuator exerts tensile or compressive axial load44Gripping system for mechanical testing of composites44Probe-and-socket fasteners for robotic assembly44	01 01 02 03 03 04 06 08 10 10 11 12
Perpendicular-force latch40Quick-release mechanisms40Ring springs clamp platform elevator into position40Cammed jaws in hydraulic cylinder grip sheets40Quick-acting clamps for machines and fixtures40Friction clamping devices and principles of design40Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Actuator exerts tensile or compressive axial load41Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	01 02 03 03 04 06 08 10 10 11 11
Quick-release mechanisms40Ring springs clamp platform elevator into position40Cammed jaws in hydraulic cylinder grip sheets40Quick-acting clamps for machines and fixtures40Friction clamping devices and principles of design40Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Actuator exerts tensile or compressive axial load41Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	02 03 03 04 06 08 10 10 11
Ring springs clamp platform elevator into position40Cammed jaws in hydraulic cylinder grip sheets40Quick-acting clamps for machines and fixtures40Friction clamping devices and principles of design40Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Short in-line turnbuckle41Actuator exerts tensile or compressive axial load44Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	03 04 06 08 10 10 11 12
Cammed jaws in hydraulic cylinder grip sheets40Quick-acting clamps for machines and fixtures40Friction clamping devices and principles of design40Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Short in-line turnbuckle41Actuator exerts tensile or compressive axial load41Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	03 04 06 08 10 10 11 12
Quick-acting clamps for machines and fixtures40Friction clamping devices and principles of design40Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Short in-line turnbuckle41Actuator exerts tensile or compressive axial load41Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	04 06 08 10 10 11 12
Friction clamping devices and principles of design40Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Short in-line turnbuckle41Actuator exerts tensile or compressive axial load41Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	06 08 10 10 11 12
Detent designs for stopping mechanical movements40Spring-loaded chucks and holding fixtures41Short in-line turnbuckle41Actuator exerts tensile or compressive axial load41Gripping system for mechanical testing of composites41Probe-and-socket fasteners for robotic assembly41	08 10 10 11 12
Spring-loaded chucks and holding fixtures4Short in-line turnbuckle4Actuator exerts tensile or compressive axial load4Gripping system for mechanical testing of composites4Probe-and-socket fasteners for robotic assembly4	10 10 11 12
Short in-line turnbuckle4Actuator exerts tensile or compressive axial load4Gripping system for mechanical testing of composites4Probe-and-socket fasteners for robotic assembly4	10 11 12
Actuator exerts tensile or compressive axial load4Gripping system for mechanical testing of composites4Probe-and-socket fasteners for robotic assembly4	11 12
Gripping system for mechanical testing of composites4Probe-and-socket fasteners for robotic assembly4	12
Probe-and-socket fasteners for robotic assembly 4	
	13
CHAPTER 11. KEY EQUATIONS AND CHARTS FOR DESIGNING MECHANISMS 41	15
Designing geared five-bar mechanisms 4	16
Kinematics of intermittent mechanisms—the external geneva wheel 42	20
Kinematics of intermittent mechanisms—the internal geneva wheel 42	23
Equations for designing cycloid mechanisms 42	26
Designing crank-and-rocker links with optimum force transmission 42	29
Design curves and equations for gear-slider mechanisms 43	32
Designing snap-action toggles 43	36
Feeder mechanisms for angular motions 43	39
Feeder mechanisms for curvilinear motions 44	40
Roberts' law helps to find alternate four-bar linkages 44	43
Ratchet layout analyzed 44	44
Slider-crank mechanism 44	45
CHAPTER 12. NEW DIRECTIONS IN MACHINE DESIGN 44	17
Low-cost software brings 3-D drawing to personal computers 44	48
Rapid prototyping verifies design and speeds time to market 44	50
Micromachines open a new frontier for machine design 45	54
INDEX 45	