Contents

Pr	eface '	To The Sixth Edition	v
1.	Intr	oduction	1
	1.1	The Fields of Development	2
	1.2	Classification of Machine Tools	2
	Esta	blishing and Expansion of Machine Tools Industry	14
		clusion	16
2.	Dete	ermination of the Forces Acting on the Tool in Certain	
	Mac	hining Operations and Horse-power Requirement	17
	2.1	Determination of the Tool Forces in a Lathe Operation	18
	2.2	Calculation of Forces Acting on Milling Cutter and	
		Determination of the Power Consumption of the Machine	24
	2.3	Calculation of Power Consumption in Cylindrical Grinding	
		Operation	27
	2.4	Determination of the Thrust on a Drill and the Power	
		Consumption	28
	2.5	Determination of the Forces Acting on a Broach and Power	
		Consumption in the case of Broaching Machine ^[6]	31
	2.6	Determination of the Forces Acting on a Shaping Tool	
		and the Power Calculation in Shaping Machine	32
3.	Kine	ematics of Machine Tools	36
	3.1	Classification and Choice of Driving System	36
	3.2	Basic Consideration in the Design of Drives	37
	3.3	Determination of Variable Speed Range in Machine Tools	38
	3.4	Graphical Representation of Speed and Structure Diagram	43

	3.5	Various Types of Structure Diagram	47
	3.6	Selection of Optimum Ray Diagram	50
	3.7	Difference Between Number of Teeth of Successive Gears	in a
		Change Gear Block	51
	3.8	Analysis of a Twelve-Speed Gear Box	53
	3.9	Standardisation of speed ratios	55
	3.10	Compound Ray Diagram	56
	3.11	Feed Gear Boxes	57
	3.12	Strength Calculation of Gears	59
	3.13	Rigidity of Grinding Wheel-workpiece System in an	
		Internal Grinder ⁽⁸⁷⁾	62
4.	Furtl	her Studies On Kinematics	76
	4.1	Transmission in Stepped Regulation	76
5.	Stepl	ess Regulation In Machine Tools	89
	5.1	Classification	89
	5.2	Mechanical Faction Drive	90
	5.3	Methods of Increasing the Range of Regulation in Modern	
		Machine Tools	95
	5.3	Semi Toroidal Drive	99
	5.4		100
	5.5	Friction Loss in Friction Variators due to Loss in Sliding Velocity	101
	5.6	Principles of Self-locking in Variator	101
	5.7	Further Analysis of Ball Variators	102
	3.7	Tuttlet Alialysis of Ball Variators	104
6.	Macl	hine Tool Guides	106
	6.1	Classification of Guides used in Machine Tool	106
	6.2	Wearing of Guides	106
	6.3	Guide Materials	110
	6.4	Temperature Deformation of Guides	111
	6.5	Liquid Friction in Guides	112
	6.6	Kinetic Friction and Stick-slip Vibration	117
	6.7	Specimen Calculation for Guides having Lubrication Wedge	119
	6.8	Methods of Calculating Pressure on Guides	121
	6.9	Guides having Rolling Friction	126
	6.10		120
	0.10	Effect of Lubrication	128
	6.11	Fundamental Types of Circular Guides	131
	0.11	i discussional Lipos of Orional Outdoor	131

			ix
	6.12	Accuracy and Wear of Machine Tool Guides	131
	6.13	Hardness of the Different Guide Materials	133
	6.14	Design of Guides under Hydrostatic Lubrication	134
	6.15	Type of Hydrostatic Slides	138
	6.16	Hydraulic Load Relief	139
	6.17	Oil Pocket Shape and Dimensions	140
	6.18	Gas Film Lubrication	141
	6.19	Design Procedure for Aerostatic Slideways	143
	6.20	Influence of Hardness of Material on Guide Wear	145
	6.21	Effect of Surface Preparation	145
	6.22	Effect of Micro-Structure and Chemical Composition	146
	6.23	Effect of Surface Pressure	146
	6.24	Seizure and Tearing of Guides	146
	6.25	Error Contribution to the Job Due to Longitudinal Wear	
		on Lathe Guides	147
	6.26	Contact Deformation of Guides	147
	6.27		148
	6.28	3	150
		Fabricated Guides	150
	6.30	Error Estimation in Guide Design	150
7.	Design of Beds, Tables and Columns		
	7.1	Various Types of Beds Used in Machine Tools-Their	
		Construction and Design Features	153
	7.2	Determination of the forces acting on the horizontal table	
		or a vertical boring machine	157
	7.3	Column Design of a Milling Machine and Maximum	
		Deflection Error in a Milling Machine	161
	7.4	Column Design of Drilling Machine	162
	7.5	Stiffness and Natural Frequency of Machine Beds	164
8.	Design of Power Screws of Machine Tools		169
	8.1	Types and Classification	169
	8.2	Design Calculations	. 171
	8.3	Strength of Lead-screw	173
	8.4	Ball Recirculating Power Screw Assemblies	175
	8.5	Calculation for the Maximum Static Load	178
	8.6	Efficiency of the Ball Recirculating Power Screw	180
	8.7	Compensation of 'Backlash' in Ordinary Sliding Screw	
		Assemblies	183
	8.8	Vertical Roller Feed Screw	184

	8.9	Distribution of Load Between the Threads of Nut in	
		the Power Screw with Sliding Friction	188
	8.10	Load Distribution on the Threads of the Nut of Ball	
		Recirculating Screw Assembly	192
	8.11	Analysis of Axial Load and Contact Rigidity of a	
		Recirculating Ball Screw	202
	8.12	Evaluation of the Rigidity	203
	8.13	Sensitivity Analysis	205
	8.14	A Critical Analysis	205
	8.15	Analysis of Preload	206
	8.16	Standard Dimensions of Recirculating Rail Screw Assembly	211
	8.17	Calculation for Dynamic Loading	213
9.	Spine	dle Units in Machine Tools	215
	9.1	Spindles and Their Supports :-Special Features, Material	
		and Construction	215
	9.2	Typical Spindle Ends	215
	9.3	Spindle Supports	217
	9.4	Calculation on Sleeve Bearing	220
	9.5	Ball Bearings	221
	9.6	Adjustments of Ball Bearings	222
	9.7	Roller Bearings	223
	9.8	Rigidity of Spindle Units	224
	9.9	Rigidity of the Rolling Friction Supports	226
	9.10	Magnitude of Deflection at the Free end of the Spindle	228
10.		ication and Rigidity in Machine Tools	230
		Introduction	230
	10.2	Steps in Selecting Proper Lubrication Oil	230
		Frictional Condition of Working	231
		Specification of Lubrication Oils	235
		Rigidity of Machine Tool Units	237
	10.6	~ ·	241
	10.7	e .	244
	10.8	Dynamic Rigidity of a Machine Tool	245
11.	Cont	rolling Systems in A Machine Tool	247
	11.1	Classification	248
	11.2	Single-Disc Selective Speed Changing System	255

			xi
12.	Electi	rical Equipments in Machine Tools	258
		Basic Ideas	258
	12.2	Selection of Motor for any Executive Organ of a	
		Machine Tool	259
	12.3	Regulation of Speed in Electrical Control	260
		Circuit Diagram for Starting the Driving Motor of a	
		Machine Tool	264
	12.5	Electrical Brakes	265
	12.6	Electromagnets used in Machine Tools Control	265
	12.7	Electromagnetic Clutch	267
	12.8	Ferromagnetic Powder, Clutch	270
	12.9	Reversing Mechanism of a Light Duty Planing Machine	271
	12.10	Thermal Relay in Machine Tools	272
	12.11	Electrical Automation in Horizontal Drilling Machine	273
	12.12	Automatic Lifting of Tool During the Return Stroke of	
		a Planing Machine	276
	12.13	Basic Ideas into Regime of Working of Motors	277
	12.14	Classification of Automatic and Semiautomatic Controls	283
13.	Hydr	aulic Control System in Machine Tools	286
	13.1	Introduction	286
	13.2	Typical Hydraulic Systems in a Machine Tool	287
	13.3	Elements of Hydraulic Systems in Machine Tools	291
		Resistance Encountered in Flow Through Pipe	291
	13.5	Evaluation of Basic Parameters for Design	292
	13.7	Energy Losses	295
	13.8	Compressibility Factor	295
	13.9	Efficiency of Hydraulic Pump Considering Losses	296
14.	Progr	ramme Control in Machine Tools	297
	14.1	Introduction	297
	14.2	Automation in Machine Tools	297
	14.3	Magnetic tape Controlled Machine Tool	299
	14.4	Photoelectric Tracing System	300
	14.5	Principles of Numerical Control	302
	14.6	Method of Disposition of Punched Holes in Cases of	
		Binary and Decimal	306
	14.7	Principle of Operation of NC Systems	307
15.	Built-	-in-inspection Units in Machine Tools	310
	15.1	Introduction	310

	15.2	Systems of automatic Inspections	311
	15.3	Some Typical Built-in-inspection Equipments	311
	15.4	Characteristic Features in Designing	314
	15.5	Conclusion	315
16.	Vibr	ation in Machine Tools	316
	16.1	Introduction	316
	16.2	Forced vibration	316
	16.4	Self-excited Vibration in Machine Tools	320
	16.5	Other Types of Forced and Damped Vibration	322
	16.6	Stick-Slip Vibration in Machine tools	325
	16.7	Minimization of Stick-Slip Vibration in Machine Tools	331
	16.8	Vibration Isolated Tool Holders	339
17.	Micr	odisplacements in Machine Tools	343
	17.1	Introduction	343
	17.2	Magnetostrictive Drive	343
	17.3	Thermodynamic Drive	347
	17.4	Minimisation of Positional Error by the Use of Oscillating	
		Normal Force	349
	17.5	Recirculating Ball Screws	350
	17.6	Surface Topography and Contact Stiffness	351
	17.7	Error Due to Stick Slip Motion	352
18.		Concepts in Machine Tools Design	356
	18.1	Introduction	356
	18.2	Probability Concept in Design	357
	18.3	Unified Systems Approach to Machine Tools Problems	359
19.	Indu	strial Robots and Their Applications	367
	19.1	Introduction	367
	19.2	Basic functions of robotic elements	368
	19.3	Mobility of Robots	370
	19.4	Reliability in Operation	372
	19.5	Control	373
	19.6		377
		Sensing	378
	19.8	Assembly and Megassembly Robots	379
20.	NC-0	CNC-DNC Machines	381
	20.1	Introduction	381

			xiii
	20.2	Principles of a CNC Machine	382
		Classification of CNC or NC Machines Through	
		Control Axes	382
	20.4	Open and closed loop control systems in N.C.,	
		C.N.C. Machines	386
	20.5	Working of N.C. Machine Tool	387
		Transducers and Monitoring of Displacement	. 387
	20.7	N.C. Retrofitting	398
	20.8	Programme and Compoter-man Interaction	401
	20.9	Present status	401
	20.10	Electronics Revolution and Computer Growth	402
	20.11	Direct Numerical Control (DNC)	404
	20.12	Part programming	406
	20.13	Part Programming	407
	20.14	CNC Lathe	412
	20.15	Machining Centre HMT-KTM (Horizontal	
		Machining Centre)	412
	20.16	A few commonly used terminology in NC, CNC	416
21.	Robo	t Language-state of the Art	418
		Introduction	418
	21.2	Robot Language Outline	420
		General Description of Programming Language	420
		Real Time	420
		Geometric Modelling	421
		Tool and object sets of coordinate axes	422
		Movements	423
		Sensors	424
	21.9	Tools	425
	21.10	Example of programming	425
		Some Commercial Languages	426
		Conclusions	428
22.	Flexil	ole Manufacturing System	430
	22.1	Introduction	430
		FMS-its Meaning, Objectives and Significance	430
		Classification of FMS	433
		"BUILDING BLOCK" Concept	433
		CNC Machining Centre	434
		CAD CAM-FMS	435
	22.7	Precision Movement	437

23.	Dyna	amic Analysis of A Few Sub-systems in Machine Tools	441
	23.1	System Analysis to Study Dynamic Compliance	442
	23.2	Spindle Supports	445
	23.3	Thermal Deformation of Supports	448
	23.5	Tribological Considerations	450
	23.6	Calculation of Rigidity Considering Finite Element ⁽¹²⁷⁾	454
24.	Non-	uniform Microdisplacement	460
	24.1	Calculations for Non-Uniform microdisplacement	460
	24.2	Non-dimensional Parameters	461
	24.3	Minimisation of Positional Displacement Error	463
	24.4	Distribution of Hydrodynamic Force in Specific Lubrication	
		Pocket	463
	24.5	Dynamic Load Rating of Spindle Supports	465
	24.6	Rigidity of Spindle unit and Optimum overhang of the Spind	le
		end:(126, 127)	466
	24.7	Accuracy of the Spindle Units	468
25.	Relia	ability Analysis of Some Machine Tool Elements	470
	25.1	Introduction	470
	25.2	Collet Chucking Analysis	471
	25.3	Analysis of Spindle with Linear Elastic Supports and	
		Viscous Damping	477
26.	Ques	tions	483
	(A)	Questions	483
	(B) A	answers	498
Glo	ssary		517
Ref	erenc	es	519
Ind	lex		529