

Table of Contents

1	OUTLINE OF CAD/CAM/CAE	1
1.1	Introduction	1
1.2	CAD System	1
1.3	CAM System	3
1.4	CAE System	5
1.5	3D CAD Systems	6
2	3D CAD SYSTEMS AND SOLID MODELS	9
2.1	Introduction	9
2.2	How to Represent Solids	9
2.3	Advantages of a Solid Modeler	12
2.4	Representation of Objects in a Solid Modeler	14
2.4.1	CSG and boundary representations	14
2.4.2	Hybrid systems	16
2.4.3	Other representation methods	17
2.5	Comparison of CSG and Boundary Representations	19
3	SOLID MODELER DESIGNBASE	23
3.1	Introduction	23
3.2	Features of DESIGNBASE	23
3.3	Software Structure of DESIGNBASE	25
3.4	Data Structure of Boundary Representations	26
3.4.1	Solid models with boundary representations	27
3.4.2	Data structures of boundary representations	28
3.4.3	Data structure of topological elements in DESIGNBASE	33
3.4.4	Data structure of geometric elements in DESIGNBASE	35
3.5	Primitive Operations	37
3.5.1	Topological elements and Euler formula	37
3.5.2	Euler operations	38
3.5.3	Primitive operations in DESIGNBASE	40
3.6	An Example of Primitive Operations	45

4	FREE-FORM CURVES	51
4.1	Introduction	51
4.2	Parametric Curves	51
4.2.1	Algebraic representation	51
4.2.2	Parametric representation	52
4.3	Bézier Curves	53
4.3.1	How to represent Bézier curves	54
4.3.2	Division and connection of Bézier curves	57
4.3.3	Degree elevation of Bézier curves	58
4.4	Rational Bézier Curves	59
4.4.1	How to represent rational Bézier curves	59
4.4.2	Weights and their effects	60
4.4.3	Creation of conic sections	60
4.5	B-Spline Curves	62
4.5.1	How to represent B-spline curves	62
4.5.2	Knot vectors and curves	64
4.5.3	Connection and division of curves	65
4.6	NURBS	66
4.6.1	How to represent NURBS	67
4.6.2	How to represent conic sections with NURBS	67
4.6.3	Connection of curves	68
4.7	Programs	69
4.7.1	Program to obtain coordinates on a curve	70
4.7.2	Program to obtain a derivative vector on a curve	74
4.7.3	Program to divide a curve	77
5	FREE-FORM SURFACES	83
5.1	Introduction	83
5.2	Quadric Surfaces	83
5.3	Parametric Patches	84
5.4	Coons Surfaces	85
5.5	Bézier Surfaces	89
5.6	Rational Bézier Surfaces	91
5.7	NURBS	93
5.8	Gregory Patches	94
5.9	Rational Boundary Gregory Patches	96
5.10	Connection of Patches	98
5.10.1	Conditions on connectivity	99
5.10.2	Connection of Gregory patches	99
5.10.3	Connection of rational boundary Gregory patches	102
5.11	Interpolation of Patches	104
5.11.1	Irregular meshes	104
5.11.2	Interpolation of curve meshes	105
5.11.3	Interpolation of triangular surfaces	107

5.11.4	Interpolation of surfaces containing an odd number of sides	108
5.11.5	Interpolation of surfaces containing an even number of sides	110
5.11.6	Interpolation of curve meshes containing T-nodes	111
5.12	Transformation of Patches	112
5.12.1	Transformation between Bézier surface and Coons surface	112
5.12.2	Transformation of rational boundary Gregory patch into rational Bézier surface	113
5.13	Programs	115
5.13.1	Program to obtain coordinates on a surface	116
5.13.2	Program to obtain a partial derivative vector of a surface	127
6	INTERSECTION CALCULATIONS	139
6.1	Introduction	139
6.2	Intersection Calculations Between Curves	139
6.2.1	Algebraic calculation method	139
6.2.2	Geometric calculation method	142
6.3	Intersection Calculations Between a Curve and a Surface	147
6.3.1	Algebraic calculation method	148
6.3.2	Geometric calculation method	149
6.4	Intersection Calculations Between Surfaces	150
6.4.1	Intersection calculations between quadratic surfaces . .	151
6.4.2	Intersection calculations between free-form surfaces . .	156
6.4.3	Recursive subdivision method	157
6.4.4	Marching method	159
6.5	Intersection Calculation in DESIGNBASE	163
7	LOCAL OPERATIONS	165
7.1	Introduction	165
7.2	Creation and Modification of Solids with Surfaces	165
7.2.1	Defining surfaces by skinning	165
7.2.2	Defining surfaces by translating control points	166
7.2.3	Defining surface by interpolation	167
7.2.4	Defining surfaces by Boolean operations	167
7.3	Primitive Solid Generation	167
7.3.1	Creation of a parallelepiped and a cylinder	168
7.3.2	Creation of a rotational model	169
7.3.3	Creation of a mirror-image model	170
7.3.4	Creation of a skinning model	170
7.3.5	Creation of a sweep model	171
7.4	Local Modification Operations	171
7.4.1	Creation and modification of edges	172
7.4.2	Lifting operation	174
7.4.3	Model cutting	175
7.4.4	Model gluing	176

7.5	Programs of Local Operations	177
8	BOOLEAN OPERATIONS	183
8.1	Introduction	183
8.2	Boolean Operations of Solids with Free-Form Surfaces and Their Problems	183
8.2.1	Intersection calculations	183
8.2.2	How to deal with intersection curves	184
8.3	Boolean Operation Algorithm in DESIGNBASE	187
8.3.1	Intersection calculations between edges and surfaces	188
8.3.2	Intersection calculations between surfaces	189
8.3.3	Creation of intersection vertices	191
8.3.4	Creation of intersection edges	192
8.3.5	Classification of boundaries and deletion of unnecessary parts	192
8.3.6	Gluing of two solids	194
8.3.7	Examples of execution	194
9	ROUNDING OPERATION	197
9.1	Introduction	197
9.2	Problems with the Rounding Operation	197
9.3	Rounding Operation in DESIGNBASE	198
9.4	Example of Rounding Operation Execution	199
9.5	Algorithm of Rounding Operation	201
9.6	How to Calculate Trajectories Drawn by Tangent Points	202
10	FUNCTIONS IN AIDING DESIGN	207
10.1	Introduction	207
10.2	Parametric Design	207
10.3	UNDO · REDO Operations	209
10.3.1	Interactive system	209
10.3.2	UNDO · REDO operations in DESIGNBASE	209
10.3.3	Representation of the solid creation process	211
10.3.4	UNDO · REDO with Boolean operations	212
10.4	Creation of Similar Shapes	213
10.4.1	Limits of the UNDO · REDO operations	213
10.4.2	Reexecution function	213
10.4.3	Limits of reexecution function	216
11	RENDERING	217
11.1	Introduction	217
11.2	Color Components and Shading Model	218
11.2.1	Color representation	218
11.2.2	Ambient light	219
11.2.3	Diffuse reflection light	219
11.2.4	Specular reflection light	220

11.2.5	Transmission light	223
11.3	Z-Buffer Method	224
11.4	Scan Line Method	224
11.4.1	Characteristics of scan line method	224
11.4.2	Actual processing in the scan line method	225
11.4.3	Coherence in the scan line method	226
11.4.4	Antialiasing — A-buffer method	227
11.5	Ray Tracing Method	228
11.5.1	Antialiasing in the ray tracing method	230
11.6	Mapping Method	231
11.6.1	Significance of mapping	231
11.6.2	Texture mapping	231
11.6.3	Reflection mapping	232
11.6.4	Refraction mapping	233
11.6.5	Bump mapping	234
11.6.6	Solid texture	234
12	MASS PROPERTIES	235
12.1	Introduction	235
12.2	How to Obtain Surface Area	235
12.2.1	Monte Carlo method	235
12.2.2	Element subdivision method	236
12.2.3	Polygonization	237
12.2.4	Numerical integration	237
12.3	How to Obtain Volume, Center of Gravity, and Moment of Inertia	239
12.3.1	Monte Carlo method	239
12.3.2	Element subdivision method	240
12.3.3	Method using integration theorem	241
12.4	Mass Property Calculation in DESIGNBASE	242
13	3-DIMENSIONAL MODELING METHOD	245
13.1	Introduction	245
13.2	Resin Model Creation System	245
13.2.1	Fundamental principles	245
13.2.2	UV curing resin	246
13.2.3	Laser control	247
13.2.4	Data processing	248
13.3	Link with Modeler	250
13.3.1	Link with surface modeler	251
13.3.2	Link with solid modeler	252
13.4	DESIGNBASE and Resin Model Creation System	253
14	SOLID MODELS AND STRUCTURE ANALYSIS	255
14.1	Introduction	255
14.2	History of Finite Element Method	255
14.3	Finite Element Method and Solid Models	257

14.4 3-Dimensional Mesh Generation	258
14.5 KSWAD — Integrated CAE System	260
14.5.1 How to apply data of solid modeler	260
14.5.2 Genuine automatic meshing	262
14.5.3 Mapped meshing	264
14.5.4 Examples of analyses by KSWAD	267
References	269
Index	279