Chapter - 6

RESULTS AND DISCUSSIONS

CHAPTER - VI

RESULTS AND DISCUSSIONS

The present chapter discusses the validity of the developed software package. It details how the user makes use of the package for specific applications pertaining to automatic recognition of features for axi-symmetric turned components. The software developed and coded has five modules for extracting geometrical data, recognition of cylindrical features, curvature features, cross hole features and special features that are present in any component. The following examples illustrate and explain the procedure for recognition of features for typical components. The remaining test component drawings are presented in the appendix A.

6.1 JAVA PROGRAM EXECUTION

User friendly windows are designed and developed in the present package When JAVA program is executed a window opens as shown in Figure 6.1 and asks filename. If filename with .stp extension is entered and clicked OK button then a window opens as shown in Figure 6.2. This window consists of a menu ‘window’. If this is clicked then it drops seven menu items, ‘FOB’, ‘FB’, ‘FOB vertex’, ‘PLANE’, ‘CIRCLE’, ‘MAIN’ and ‘FEATURE’ as shown in Figure 6.3. The above mentioned menu items are clicked so that various windows with extracted data from STEP file in tables are opened. These details are given in Table 6.1.

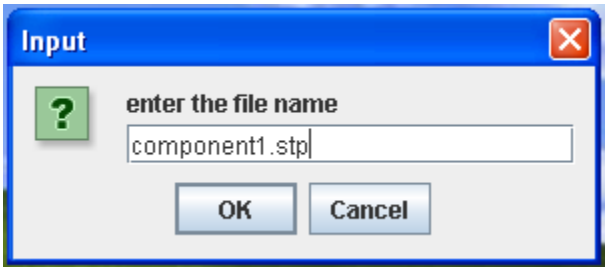


Fig. 6.1: First window asking filename

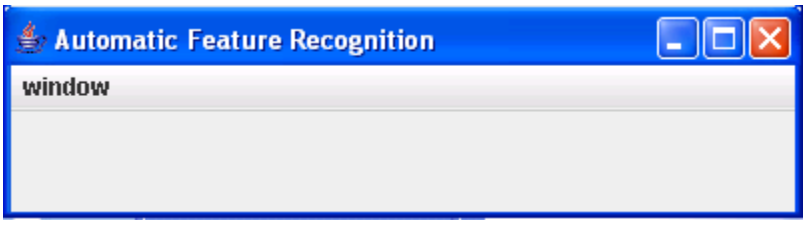


Fig. 6.2: Second window opens after entering STEP filename

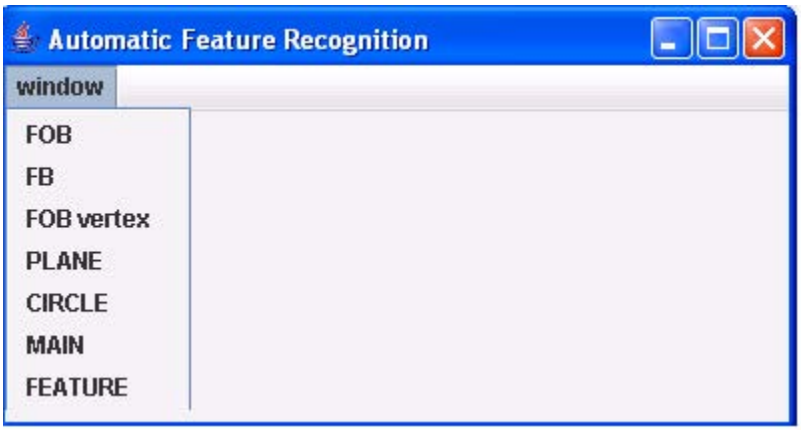


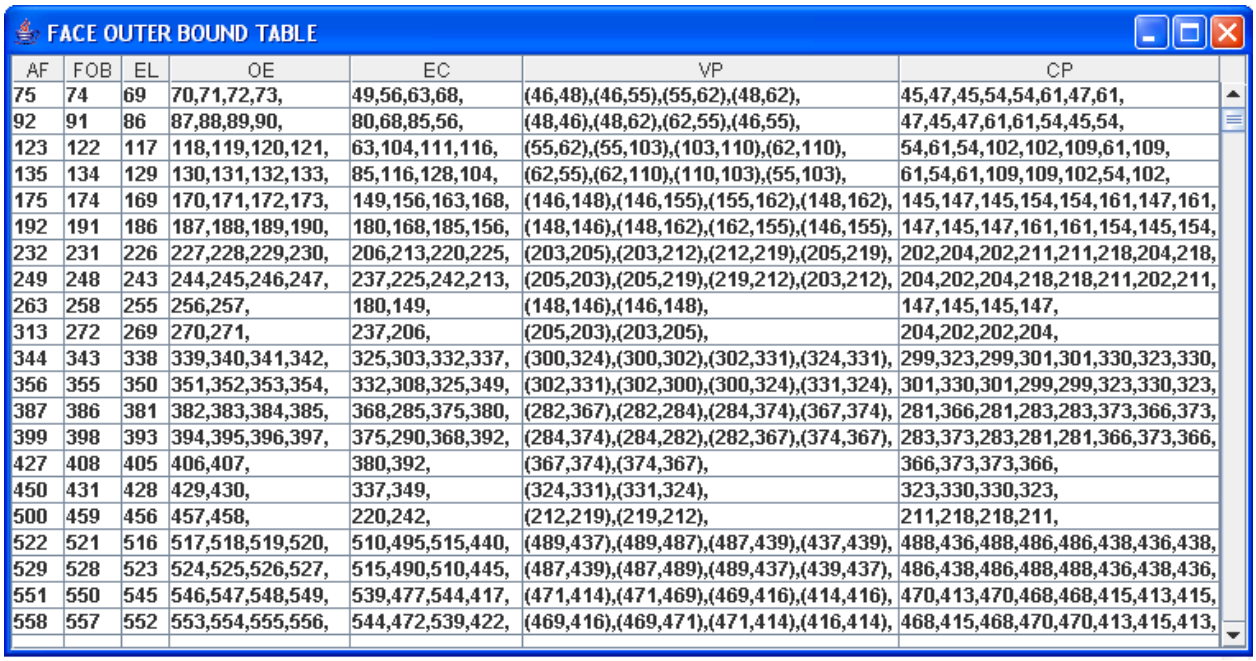
Fig. 6.3: Drop down items of 'window' menu item

Table 6.1: Extracted data in various tables when menu item clicked

Menu Item	**Figure name**	**Extracted data from STEP file in columns**
FOB	Figure 6.4	AF,FOB,EL,OE,EC,VP,CP
FB	Figure 6.5	AF,FB,EL,OE,EC,VP,CP,X,Y,Z
FOB vertex	Figure 6.6	Cpv1,x1,y1,z1,cpv2,x2,y2,z2
PLANE	Figure 6.7	AF,cysu,A2P3D,surface,Sradius,cp,Ax,Ay,Az
CIRCLE	Figure 6.8	AF,EC,circle,A2P3D,cradius,cx,cy,cz,circle/line
MAIN	Figure 6.9	AF,EC,Surface,Sradius,Ax,Ay,Az,condition,Cradius,cx,cy,cz,T/F
FEATURE	Figure 6.10	Face No., Feature No., Feature Name, Radius, Length

Column abbreviations:

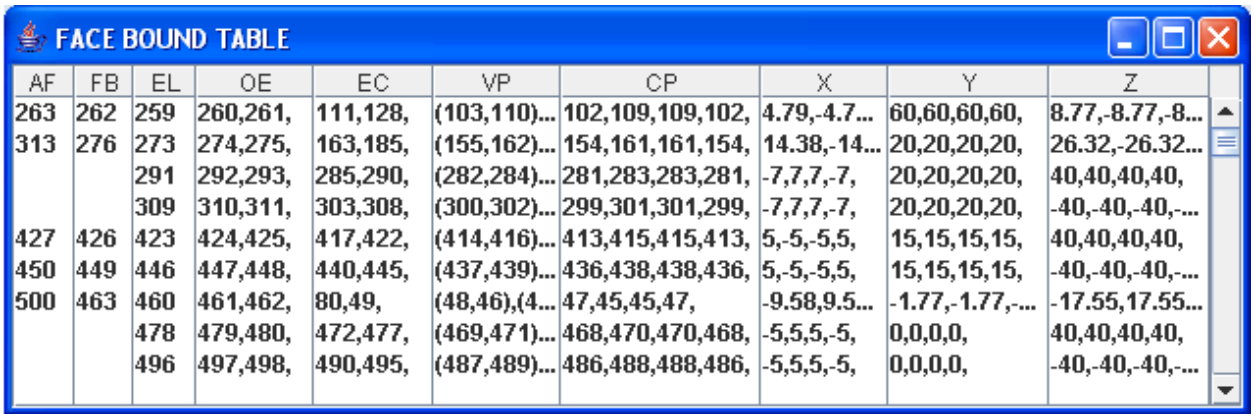
AF	-	ADVANCED_FACE entity number
FOB	-	FACE_OUTER_BOUND entity number
EL	-	EDGE_LOOP entity number
OE	-	ORIENTED_EDGE entity number
EC	-	EDGE_CURVE entity numbers
VP	-	VERTEX_POINT entity number
CP	-	CARTESIAN_POINT entity number
FB	-	FACE_BOUND entity number
X, Y, Z	-	vertex point coordinates entity number
cpv1, cpv2	-	Cartesian point entity number for two points
x1, y1,z1	-	coordinates points corresponding to cpv1
x2, y2,z2	-	coordinates points corresponding to cpv2
cysu	-	cylinder surface
A2P3D	-	AXIS2_PLACEMENT_3D entity number
Cradius	-	Circle radius
Circle/line	-	EDGE_CURVE construction(condition)
Surface	-	surface name
Sradius	-	Radius of the surface
Ax, Ay, Az	-	Surface axis coordinates
Cx, Cy, Cz	-	Circle center coordinates of circles in condition.
T/F	-	last letter in EDGE_CURVE line
CP	-	CARTESIAN_POINT(‘Axis2P3D Location’…) entity number



FACE OUTER BOUND TABLE

AF	FOB	EL	OE	EC	VP	CP
75	74	69	70,71,72,73,	49,56,63,68,	(46,48),(46,55),(55,62),(48,62),	45,47,45,54,54,61,47,61,
92	91	86	87,88,89,90,	80,68,85,56,	(48,46),(48,62),(62,55),(46,55),	47,45,47,61,61,54,45,54,
123	122	117	118,119,120,121,	63,104,111,116,	(55,62),(55,103),(103,110),(62,110),	54,61,54,102,102,109,61,109,
135	134	129	130,131,132,133,	85,116,128,104,	(62,55),(62,110),(110,103),(55,103),	61,54,61,109,109,102,54,102,
175	174	169	170,171,172,173,	149,156,163,168,	(146,148),(146,155),(155,162),(148,162),	145,147,145,154,154,161,147,161,
192	191	186	187,188,189,190,	180,168,185,156,	(148,146),(148,162),(162,155),(146,155),	147,145,147,161,161,154,145,154,
232	231	226	227,228,229,230,	206,213,220,225,	(203,205),(203,212),(212,219),(205,219),	202,204,202,211,211,218,204,218,
249	248	243	244,245,246,247,	237,225,242,213,	(205,203),(205,219),(219,212),(203,212),	204,202,204,218,218,211,202,211,
263	258	255	256,257,	180,149,	(148,146),(146,148),	147,145,145,147,
313	272	269	270,271,	237,206,	(205,203),(203,205),	204,202,202,204,
344	343	338	339,340,341,342,	325,303,332,337,	(300,324),(300,302),(302,331),(324,331),	299,323,299,301,301,330,323,330,
356	355	350	351,352,353,354,	332,308,325,349,	(302,331),(302,300),(300,324),(331,324),	301,330,301,299,299,323,330,323,
387	386	381	382,383,384,385,	368,285,375,380,	(282,367),(282,284),(284,374),(367,374),	281,366,281,283,283,373,366,373,
399	398	393	394,395,396,397,	375,290,368,392,	(284,374),(284,282),(282,367),(374,367),	283,373,283,281,281,366,373,366,
427	408	405	406,407,	380,392,	(367,374),(374,367),	366,373,373,366,
450	431	428	429,430,	337,349,	(324,331),(331,324),	323,330,330,323,
500	459	456	457,458,	220,242,	(212,219),(219,212),	211,218,218,211,
522	521	516	517,518,519,520,	510,495,515,440,	(489,437),(489,487),(487,439),(437,439),	488,436,488,486,486,438,436,438,
529	528	523	524,525,526,527,	515,490,510,445,	(487,439),(487,489),(489,437),(439,437),	486,438,486,488,488,436,438,436,
551	550	545	546,547,548,549,	539,477,544,417,	(471,414),(471,469),(469,416),(414,416),	470,413,470,468,468,415,413,415,
558	557	552	553,554,555,556,	544,472,539,422,	(469,416),(469,471),(471,414),(416,414),	468,415,468,470,470,413,415,413,

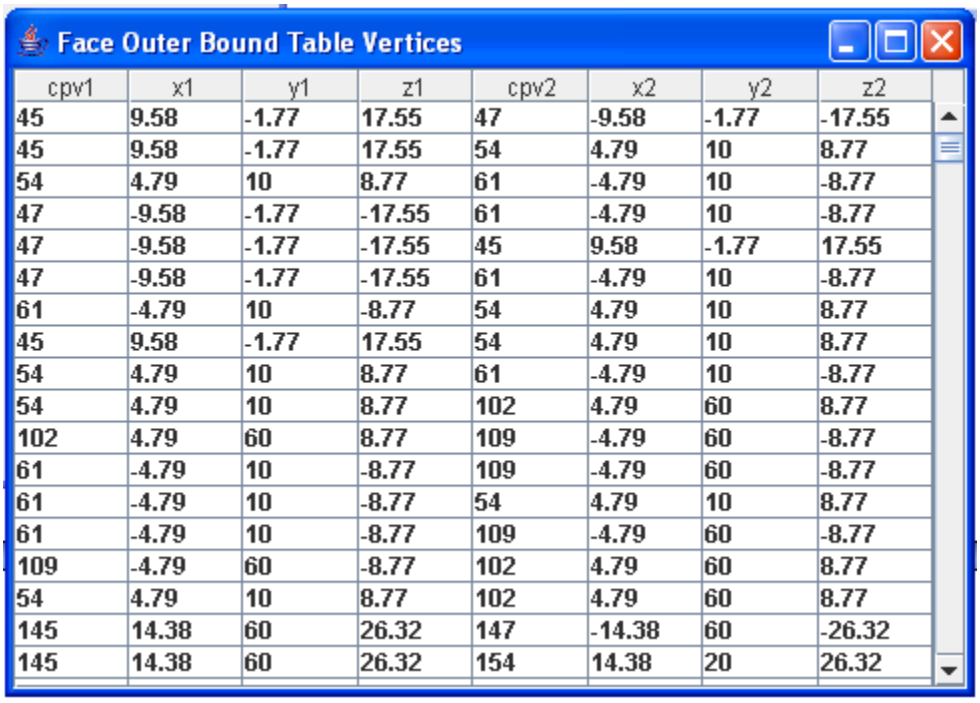
Fig. 6.4: FOB table window showing extracted data about face outer bound



FACE BOUND TABLE

AF	FB	EL	OE	EC	VP	CP	X	Y	Z
263	262	259	260,261,	111,128,	(103,110)...	102,109,109,102,	4.79,-4.7...	60,60,60,60,	8.77,-8.77,-8...
313	276	273	274,275,	163,185,	(155,162)...	154,161,161,154,	14.38,-14...	20,20,20,20,	26.32,-26.32...
		291	292,293,	285,290,	(282,284)...	281,283,283,281,	-7,7,7,-7,	20,20,20,20,	40,40,40,40,
		309	310,311,	303,308,	(300,302)...	299,301,301,299,	-7,7,7,-7,	20,20,20,20,	-40,-40,-40,-...
427	426	423	424,425,	417,422,	(414,416)...	413,415,415,413,	5,-5,-5,5,	15,15,15,15,	40,40,40,40,
450	449	446	447,448,	440,445,	(437,439)...	436,438,438,436,	5,-5,-5,5,	15,15,15,15,	-40,-40,-40,-...
500	463	460	461,462,	80,49,	(48,46),(4...	47,45,45,47,	-9.58,9.5...	-1.77,-1.77,-...	-17.55,17.55...
		478	479,480,	472,477,	(469,471)...	468,470,470,468,	-5,5,5,-5,	0,0,0,0,	40,40,40,40,
		496	497,498,	490,495,	(487,489)...	486,488,488,486,	-5,5,5,-5,	0,0,0,0,	-40,-40,-40,-...

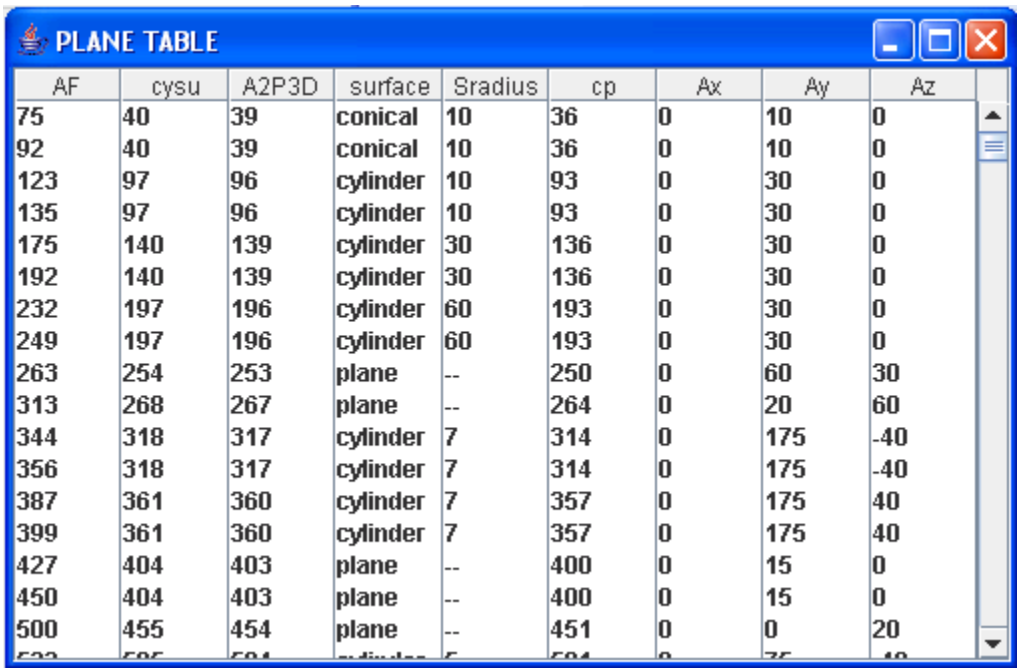
Fig. 6.5: FB table window showing extracted data about face bound



Face Outer Bound Table Vertices

cpv1	x1	y1	z1	cpv2	x2	y2	z2
45	9.58	-1.77	17.55	47	-9.58	-1.77	-17.55
45	9.58	-1.77	17.55	54	4.79	10	8.77
54	4.79	10	8.77	61	-4.79	10	-8.77
47	-9.58	-1.77	-17.55	61	-4.79	10	-8.77
47	-9.58	-1.77	-17.55	45	9.58	-1.77	17.55
47	-9.58	-1.77	-17.55	61	-4.79	10	-8.77
61	-4.79	10	-8.77	54	4.79	10	8.77
45	9.58	-1.77	17.55	54	4.79	10	8.77
54	4.79	10	8.77	61	-4.79	10	-8.77
54	4.79	10	8.77	102	4.79	60	8.77
102	4.79	60	8.77	109	-4.79	60	-8.77
61	-4.79	10	-8.77	109	-4.79	60	-8.77
61	-4.79	10	-8.77	54	4.79	10	8.77
61	-4.79	10	-8.77	109	-4.79	60	-8.77
109	-4.79	60	-8.77	102	4.79	60	8.77
54	4.79	10	8.77	102	4.79	60	8.77
145	14.38	60	26.32	147	-14.38	60	-26.32
145	14.38	60	26.32	154	14.38	20	26.32

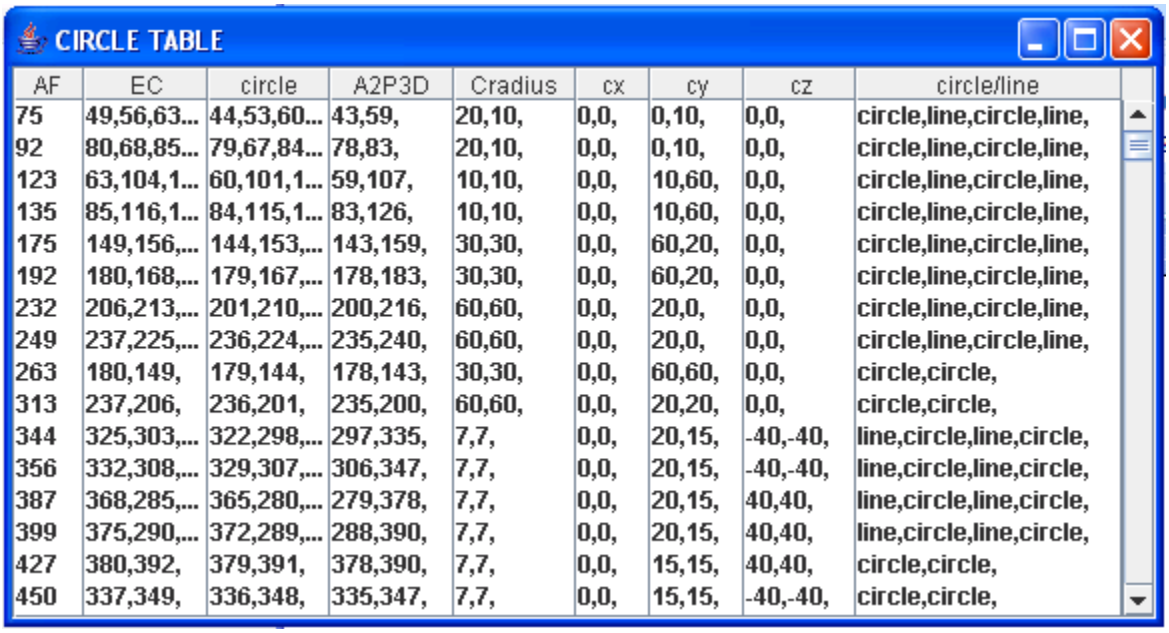
Fig. 6.6: FOB vertex table window showing extracted data about coordinates



PLANE TABLE

AF	cysu	A2P3D	surface	Sradius	cp	Ax	Ay	Az
75	40	39	conical	10	36	0	10	0
92	40	39	conical	10	36	0	10	0
123	97	96	cylinder	10	93	0	30	0
135	97	96	cylinder	10	93	0	30	0
175	140	139	cylinder	30	136	0	30	0
192	140	139	cylinder	30	136	0	30	0
232	197	196	cylinder	60	193	0	30	0
249	197	196	cylinder	60	193	0	30	0
263	254	253	plane	--	250	0	60	30
313	268	267	plane	--	264	0	20	60
344	318	317	cylinder	7	314	0	175	-40
356	318	317	cylinder	7	314	0	175	-40
387	361	360	cylinder	7	357	0	175	40
399	361	360	cylinder	7	357	0	175	40
427	404	403	plane	--	400	0	15	0
450	404	403	plane	--	400	0	15	0
500	455	454	plane	--	451	0	0	20

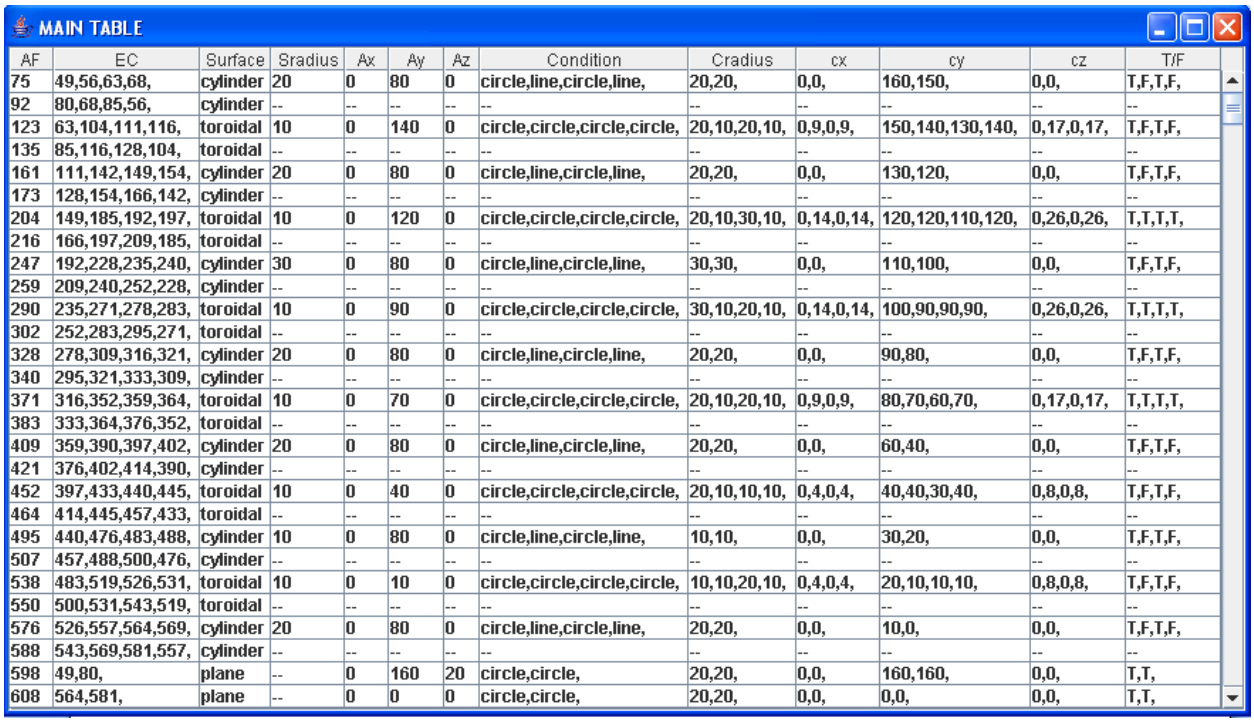
Fig. 6.7: PLANE table window showing extracted data about plane



CIRCLE TABLE

AF	EC	circle	A2P3D	Cradius	cx	cy	cz	circle/line
75	49,56,63...	44,53,60...	43,59,	20,10,	0,0,	0,10,	0,0,	circle,line,circle,line,
92	80,68,85...	79,67,84...	78,83,	20,10,	0,0,	0,10,	0,0,	circle,line,circle,line,
123	63,104,1...	60,101,1...	59,107,	10,10,	0,0,	10,60,	0,0,	circle,line,circle,line,
135	85,116,1...	84,115,1...	83,126,	10,10,	0,0,	10,60,	0,0,	circle,line,circle,line,
175	149,156,...	144,153,...	143,159,	30,30,	0,0,	60,20,	0,0,	circle,line,circle,line,
192	180,168,...	179,167,...	178,183,	30,30,	0,0,	60,20,	0,0,	circle,line,circle,line,
232	206,213,...	201,210,...	200,216,	60,60,	0,0,	20,0,	0,0,	circle,line,circle,line,
249	237,225,...	236,224,...	235,240,	60,60,	0,0,	20,0,	0,0,	circle,line,circle,line,
263	180,149,	179,144,	178,143,	30,30,	0,0,	60,60,	0,0,	circle,circle,
313	237,206,	236,201,	235,200,	60,60,	0,0,	20,20,	0,0,	circle,circle,
344	325,303,...	322,298,...	297,335,	7,7,	0,0,	20,15,	-40,-40,	line,circle,line,circle,
356	332,308,...	329,307,...	306,347,	7,7,	0,0,	20,15,	-40,-40,	line,circle,line,circle,
387	368,285,...	365,280,...	279,378,	7,7,	0,0,	20,15,	40,40,	line,circle,line,circle,
399	375,290,...	372,289,...	288,390,	7,7,	0,0,	20,15,	40,40,	line,circle,line,circle,
427	380,392,	379,391,	378,390,	7,7,	0,0,	15,15,	40,40,	circle,circle,
450	337,349,	336,348,	335,347,	7,7,	0,0,	15,15,	-40,-40,	circle,circle,

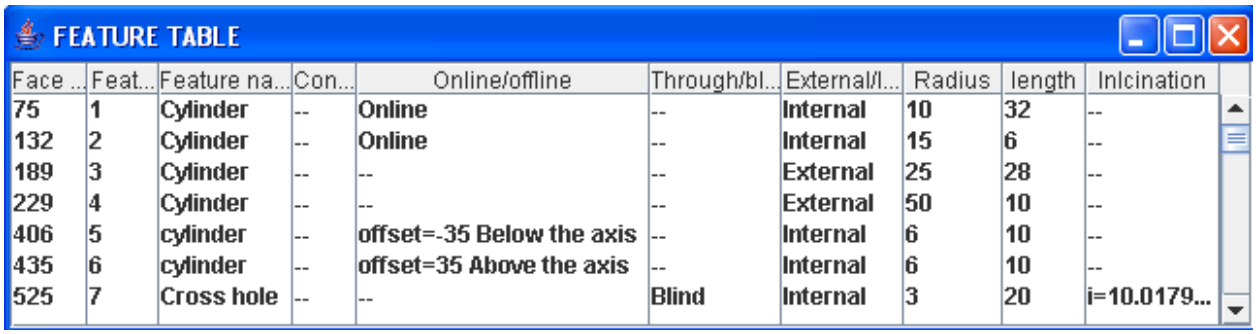
Fig. 6.8: CIRCLE table window showing extracted data about circle



MAIN TABLE

AF	EC	Surface	Sradius	Ax	Ay	Az	Condition	Cradius	cx	cy	cz	T/F
75	49,56,63,68,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	160,150,	0,0,	T,F,T,F,
92	80,68,85,56,	cylinder	--	--	--	--	--	--	--	--	--	--
123	63,104,111,116,	toroidal	10	0	140	0	circle,circle,circle,circle,	20,10,20,10,	0,9,0,9,	150,140,130,140,	0,17,0,17,	T,F,T,F,
135	85,116,128,104,	toroidal	--	--	--	--	--	--	--	--	--	--
161	111,142,149,154,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	130,120,	0,0,	T,F,T,F,
173	128,154,166,142,	cylinder	--	--	--	--	--	--	--	--	--	--
204	149,185,192,197,	toroidal	10	0	120	0	circle,circle,circle,circle,	20,10,30,10,	0,14,0,14,	120,120,110,120,	0,26,0,26,	T,T,T,T,
216	166,197,209,185,	toroidal	--	--	--	--	--	--	--	--	--	--
247	192,228,235,240,	cylinder	30	0	80	0	circle,line,circle,line,	30,30,	0,0,	110,100,	0,0,	T,F,T,F,
259	209,240,252,228,	cylinder	--	--	--	--	--	--	--	--	--	--
290	235,271,278,283,	toroidal	10	0	90	0	circle,circle,circle,circle,	30,10,20,10,	0,14,0,14,	100,90,90,90,	0,26,0,26,	T,T,T,T,
302	252,283,295,271,	toroidal	--	--	--	--	--	--	--	--	--	--
328	278,309,316,321,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	90,80,	0,0,	T,F,T,F,
340	295,321,333,309,	cylinder	--	--	--	--	--	--	--	--	--	--
371	316,352,359,364,	toroidal	10	0	70	0	circle,circle,circle,circle,	20,10,20,10,	0,9,0,9,	80,70,60,70,	0,17,0,17,	T,T,T,T,
383	333,364,376,352,	toroidal	--	--	--	--	--	--	--	--	--	--
409	359,390,397,402,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	60,40,	0,0,	T,F,T,F,
421	376,402,414,390,	cylinder	--	--	--	--	--	--	--	--	--	--
452	397,433,440,445,	toroidal	10	0	40	0	circle,circle,circle,circle,	20,10,10,10,	0,4,0,4,	40,40,30,40,	0,8,0,8,	T,F,T,F,
464	414,445,457,433,	toroidal	--	--	--	--	--	--	--	--	--	--
495	440,476,483,488,	cylinder	10	0	80	0	circle,line,circle,line,	10,10,	0,0,	30,20,	0,0,	T,F,T,F,
507	457,488,500,476,	cylinder	--	--	--	--	--	--	--	--	--	--
538	483,519,526,531,	toroidal	10	0	10	0	circle,circle,circle,circle,	10,10,20,10,	0,4,0,4,	20,10,10,10,	0,8,0,8,	T,F,T,F,
550	500,531,543,519,	toroidal	--	--	--	--	--	--	--	--	--	--
576	526,557,564,569,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	10,0,	0,0,	T,F,T,F,
588	543,569,581,557,	cylinder	--	--	--	--	--	--	--	--	--	--
598	49,80,	plane	--	0	160	20	circle,circle,	20,20,	0,0,	160,160,	0,0,	T,T,
608	564,581,	plane	--	0	0	0	circle,circle,	20,20,	0,0,	0,0,	0,0,	T,T,

Fig. 6.9: MAIN table window showing summary of extracted data



Face ...	Feat...	Feature na...	Con...	Online/offline	Through/bl...	External/I...	Radius	length	Inlcination
75	1	Cylinder	--	Online	--	Internal	10	32	--
132	2	Cylinder	--	Online	--	Internal	15	6	--
189	3	Cylinder	--	--	--	External	25	28	--
229	4	Cylinder	--	--	--	External	50	10	--
406	5	cylinder	--	offset=-35 Below the axis	--	Internal	6	10	--
435	6	cylinder	--	offset=35 Above the axis	--	Internal	6	10	--
525	7	Cross hole	--	--	Blind	Internal	3	20	i=10.0179...

Fig. 6.10: FEATURE table window showing recognized feature details

6.2 CASE STUDY - 1

Figure 6.11 shows case study 1 drawing. As shown in Figure 6.12, it consists of eight cylinders namely A, B, D, E, F, G, H and I of different diameters. Cylinder B is added to cylinder A. Cylinders D & E, F & G, H & I are subtracted. All eight cylinders are recognized with the help of developed JAVA program. The feature attributes like dimension (length and radius), nature of internal feature (through/ blind), type of feature (external/internal) and feature location relative to the original coordinates of the designed part (online/offline) are extracted. The output for case study is shown in Figure 6.13.

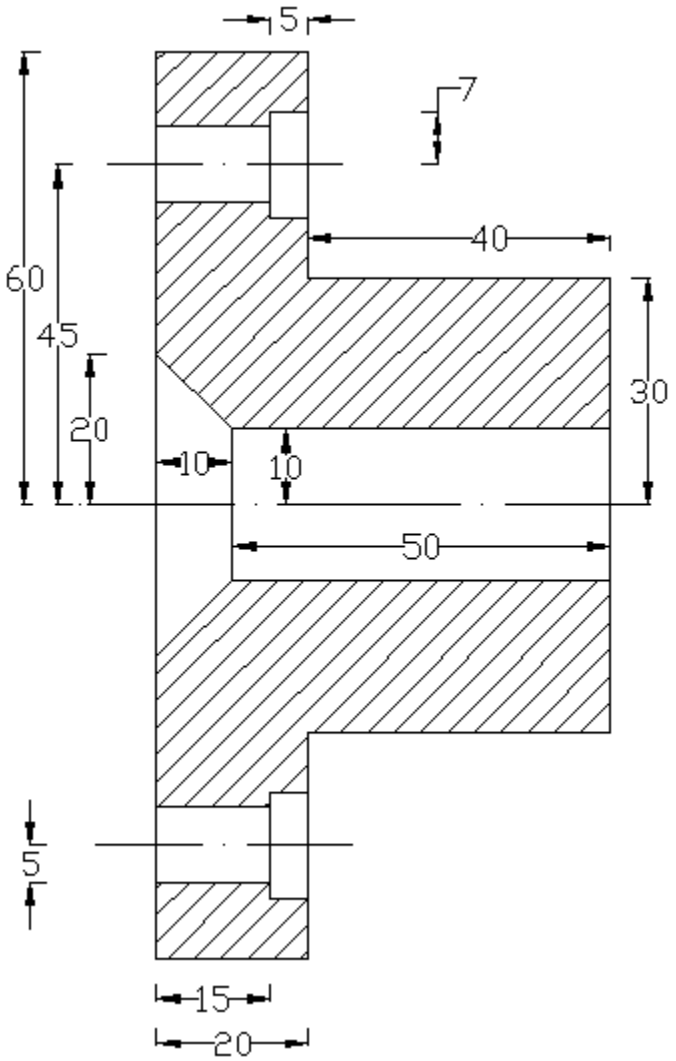


Fig. 6.11: Case study1 drawing

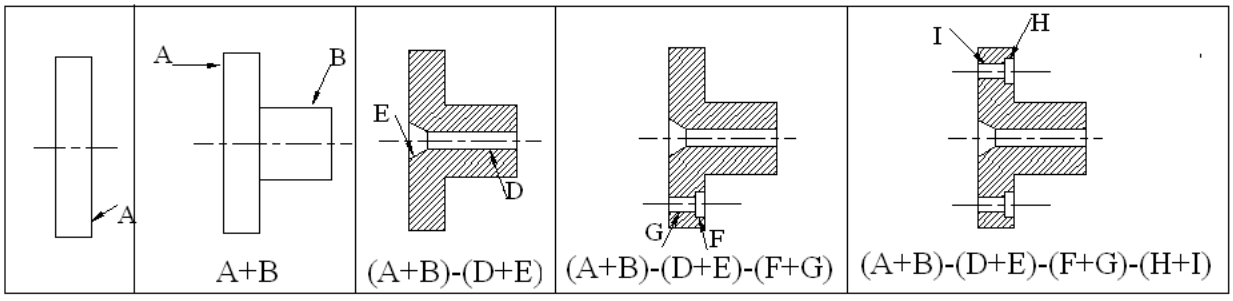


Fig. 6.12: Addition and subtraction of cylinders in case study1

FEATURE TABLE

Fac...	Feature No.	Feature n...	Conc...	Online/offline	Through/...	External/I...	Radius	length	Inlci...
75	1	Conical	--	Online	--	Internal	20,10,	10	--
123	2	Cylinder	--	Online	--	Internal	10	50	--
175	3	Cylinder	--	--	--	External	30	40	--
232	4	Cylinder	--	--	--	External	60	20	--
303	5	cylinder	--	offset=45 Above the axis	--	Internal	7	5	--
387	6	Cylinder	--	offset=-45 Below the axis	--	Internal	7	5	--
522	7	cylinder	--	offset=45 Above the axis	--	Internal	5	15	--
551	8	Cylinder	--	offset=-45 Below the axis	--	Internal	5	15	--

Fig. 6.13: Output of the case study 1

Figure 6.14 shows the recognized features for case study 1 and procedure is explained in subsections 6.2.1 to 6.2.4. Figure 6.15 shows the MAIN table output for case study 1. This table is given as input for feature recognition program. Table 6.2 shows the summary of the MAIN table and is used to explain feature recognition procedure. From this table, addition and subtraction of cylinders is done for the benefit of feature recognition. The procedure is explained in the following sections.

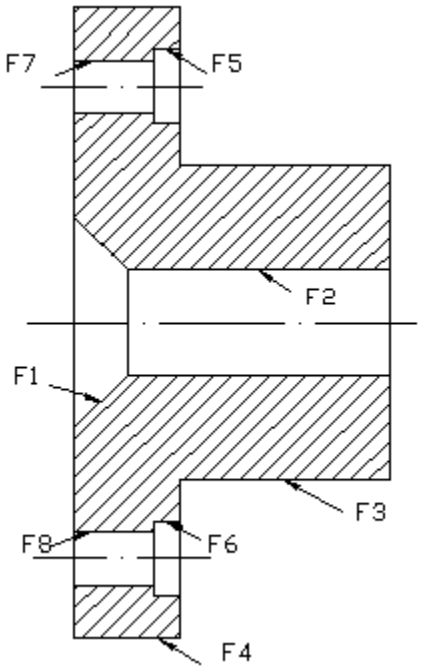


Fig. 6.14: Case study 1 with recognized features

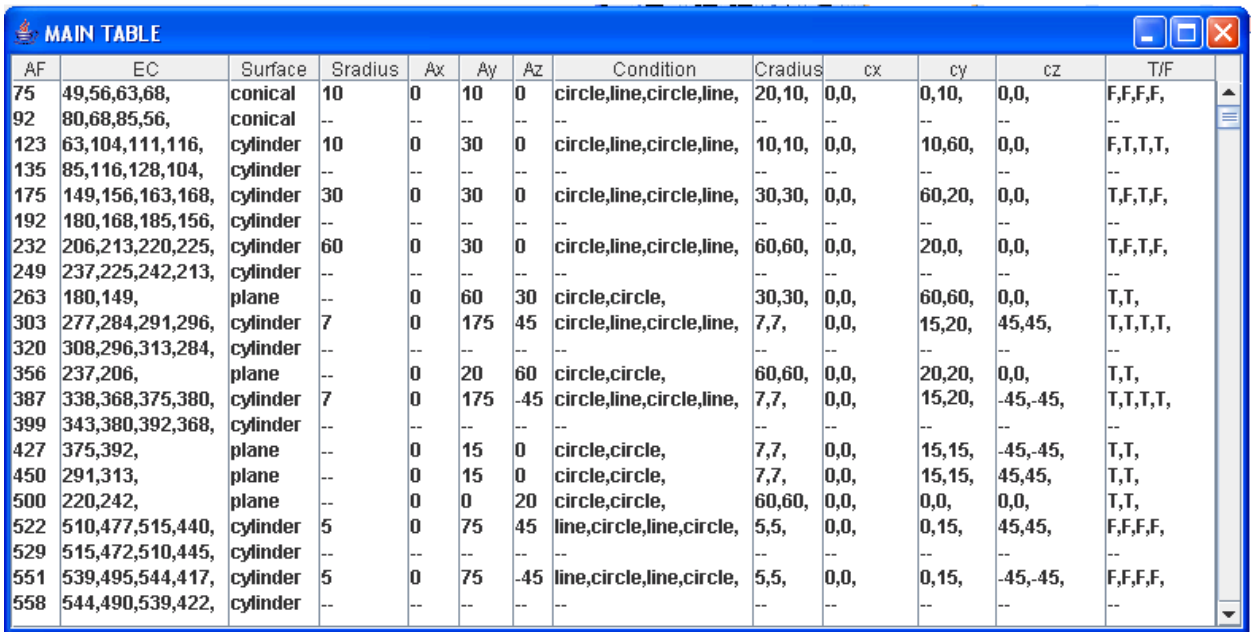


Fig. 6.15: Output of the MAIN table for case study 1

Table 6.2: Summary output of the MAIN table for case study 1

Row no.	AF	EC	Surface	Radius	X	Y	Z	EC construction
1	75	49,56,63,68,	conical	20,10,	0,0,	0,10,	0,0,	circle,line,circle,line,
2	123	63,104,111,116,	cylinder	10,10,	0,0,	10,60,	0,0,	circle,line,circle,line,
3	175	149,156,163,168,	cylinder	30,30,	0,0,	60,20,	0,0,	circle,line,circle,line,
4	232	206,213,220,225,	cylinder	60,60,	0,0,	20,0,	0,0,	circle,line,circle,line,
5	303	277,284,291,296,	cylinder	7,7,	0,0,	15,20,	45,45,	circle,line,circle,line,
6	387	338,368,375,380,	cylinder	7,7,	0,0,	15,20,	-45,-45,	circle,line,circle,line,
7	522	510,477,515,440,	cylinder	5,5,	0,0,	0,15,	45,45,	line,circle,line,circle,
8	551	539,495,544,417,	cylinder	5,5,	0,0,	0,15,	-45,-45,	line,circle,line,circle,

6.2.1 Recognition of a Cylindrical Feature

In table 6.2, fourth row shows a cylinder A, made of two circles with centers (0, 20, 0) (first value of X, Y& Z Columns) and (0, 0, 0) (second values of X, Y & Z columns) with radius of 60 each along with two lines as shown in Figure 6.16. X and Z coordinates are equal and Y value is only varying from 20 to 0. So the cylinder is symmetrical about Y axis and length of the cylinder A is difference of Y values i.e., 20. Radiuses of both circles are same (60), so it is a

longitudinal cylinder. As Y value is decreased from 20 to 0, it can conclude that cylinder A is an external cylinder.

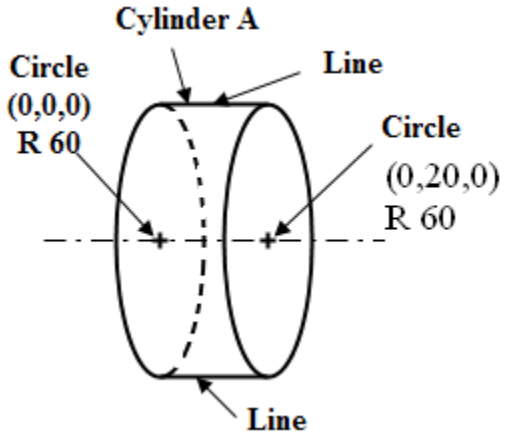


Fig. 6.16: Longitudinal cylinder

6.2.2 Recognition of Addition of a Cylindrical Feature

The third row of table 6.2 shows cylinder B as a longitudinal cylinder with radius of 30 and length as 40. Cylinder B is recognized as explained in 6.2.1. The centers of the circle 2 and circle 3 are same as shown in Figure 6.17 and Y value is increased from 20 to 60, hence, cylinder B is added to cylinder A.

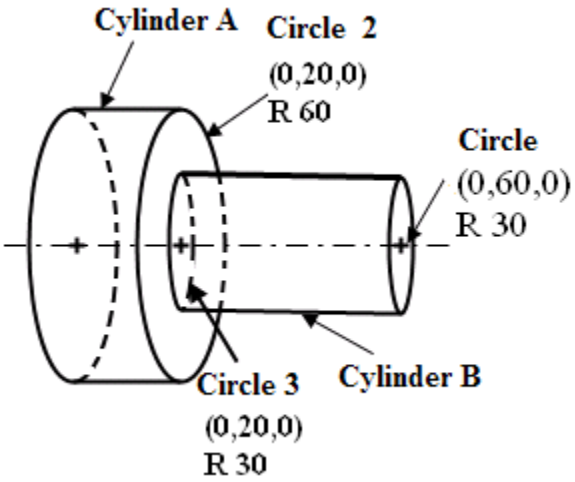


Fig. 6.17: Addition of cylinder B to cylinder A

6.2.3 Recognition of Subtraction of Cylindrical Hole Feature

The second row of table 6.2 recognizes cylinder D as explained in section 6.2.1 as a longitudinal cylinder with radius of 10 and length as 50. As shown in Figure 6.18, Y value is increased from 60 to 10, hence, the cylinder D is subtracted from cylinder A and B, so it is a cylindrical hole.

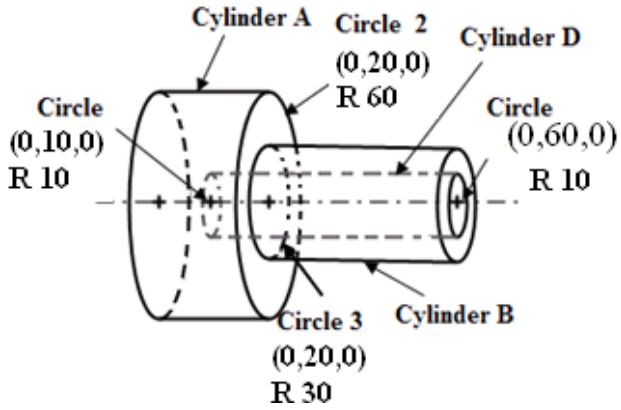


Fig. 6.18: Subtraction of cylindrical hole

6.2.4 Recognition of Subtraction of a Conical Hole Feature

The first row of table 6.2 shows two circles of unequal radius of 20 & 10, as the third column here indicates conical, so it is a conical feature E with circles 4 & 5 and with centers (0, 10, 0) and (0, 0, 0) as shown in Figure 6.19. Y value is increasing from 0 to 10, hence cylinder E is subtracted from cylinder A.

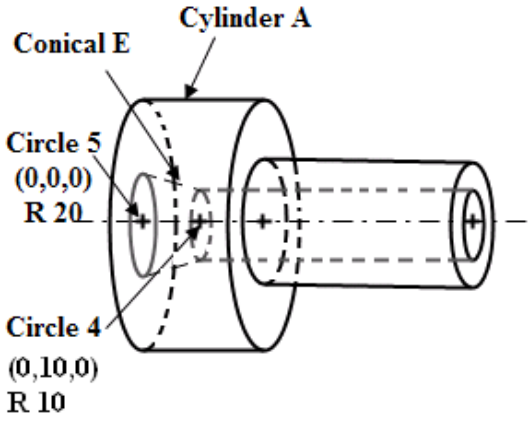


Fig. 6.19: Subtraction of Conical hole

6.3 CASE STUDY - 2

Figure 6.20 shows case study 2 drawing. It consists of thirteen features as shown in Figure 6.21 out of which seven cylinders are longitudinal and six are toroidal features. All these features are recognized with the help of developed software. The cylindrical and toroidal features dimension attributes like radius, length are recognized. The output of the case study 2 is shown in Figure 6.22. MAIN table output for case study 2 is shown in Figure 6.23. This table is given as input for feature recognition program. Table 6.3 shows the summary of the MAIN table and is used to explain feature recognition procedure.

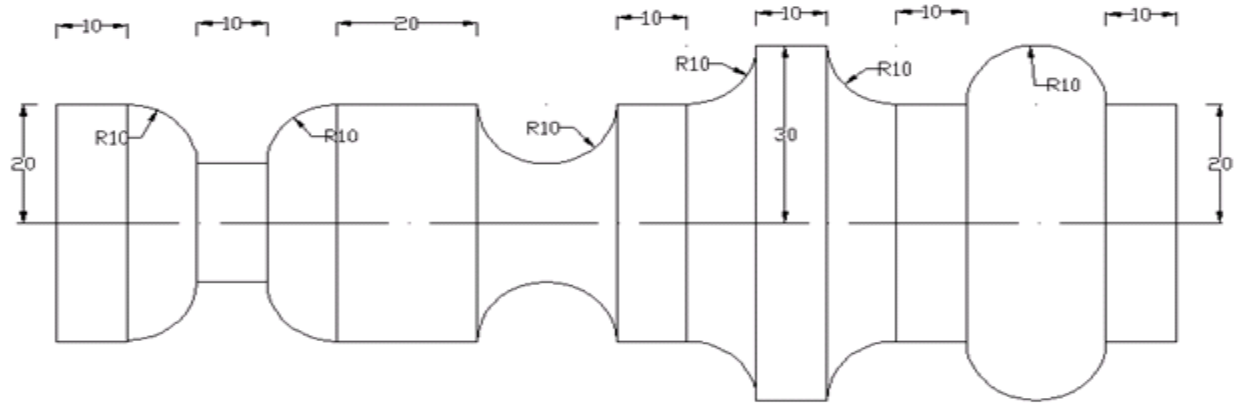


Fig. 6.20: Case study 2 drawing

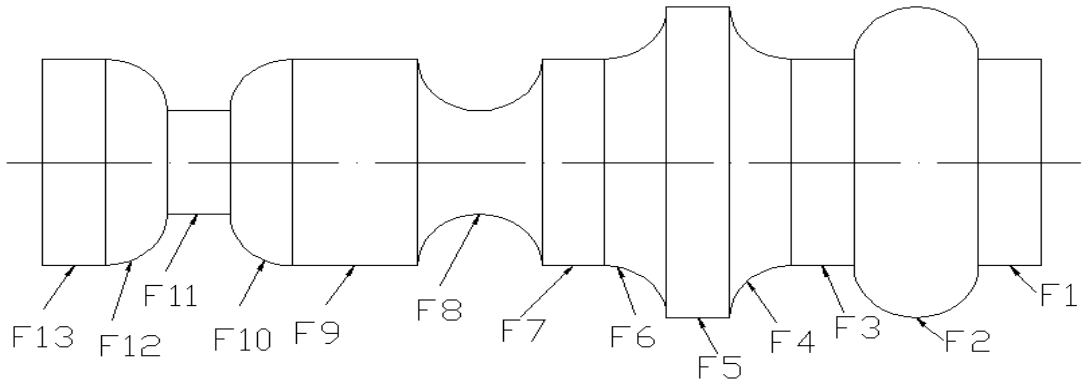


Fig. 6.21: Case study 2 with recognized features

FEATURE TABLE

Face No.	Feature No.	Feature n...	Concave/...	Online/offl...	Through/b...	External/I...	Radius	length	Inlcination
75	1	Cylinder	--	--	--	External	20	10	--
123	2	Toroidal	Convex	--	--	External	10	20	--
161	3	Cylinder	--	--	--	External	20	10	--
204	4	Toroidal	Concave	--	--	External	10	10	--
247	5	Cylinder	--	--	--	External	30	10	--
290	6	Toroidal	Concave	--	--	External	10	10	--
328	7	Cylinder	--	--	--	External	20	10	--
371	8	Toroidal	Concave	--	--	External	10	20	--
409	9	Cylinder	--	--	--	External	20	20	--
452	10	Toroidal	Convex	--	--	External	10	10	--
495	11	Cylinder	--	--	--	External	10	10	--
538	12	Toroidal	Convex	--	--	External	10	10	--
576	13	Cylinder	--	--	--	External	20	10	--

Fig. 6.22: Output of case study 2

6.3.1 Recognition of Circle Centers for Each Feature

In Table 6.3 shows cylindrical features made of two circles with centers as shown in Figure 6.24. For example, cylinder on face (A_F) 75 (first row of Table 6.3) made of two circles with centers (0, 150, 0) (first value of X, Y & Z columns) and (0, 160, 0) (second values of X, Y & Z columns) with radius of 20. Y value is increased from 150 to 160. So, cylinder is an external longitudinal cylinder. Like that on faces (A_F) 161, 247, 328, 409, 495, 576 consist of cylinders. This explanation is shown in Table 6.4.

MAIN TABLE

AF	EC	Surface	Sra...	Ax	Ay	Az	Condition	Cradius	cx	cy	cz	T/F
75	49,56,63,68,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	160,150,	0,0,	T,F,T,F,
92	80,68,85,56,	cylinder	--	--	--	--	--	--	--	--	--	--
123	63,104,111,116,	toroidal	10	0	140	0	circle,circle,circle,circle,	20,10,20,10,	0,9,0,9,	150,140,130,140,	0,17,0,17,	T,F,T,F,
135	85,116,128,104,	toroidal	--	--	--	--	--	--	--	--	--	--
161	111,142,149,154,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	130,120,	0,0,	T,F,T,F,
173	128,154,166,142,	cylinder	--	--	--	--	--	--	--	--	--	--
204	149,185,192,197,	toroidal	10	0	120	0	circle,circle,circle,circle,	20,10,30,10,	0,14,0,14,	120,120,110,120,	0,26,0,26,	T,T,T,T,
216	166,197,209,185,	toroidal	--	--	--	--	--	--	--	--	--	--
247	192,228,235,240,	cylinder	30	0	80	0	circle,line,circle,line,	30,30,	0,0,	110,100,	0,0,	T,F,T,F,
259	209,240,252,228,	cylinder	--	--	--	--	--	--	--	--	--	--
290	235,271,278,283,	toroidal	10	0	90	0	circle,circle,circle,circle,	30,10,20,10,	0,14,0,14,	100,90,90,90,	0,26,0,26,	T,T,T,T,
302	252,283,295,271,	toroidal	--	--	--	--	--	--	--	--	--	--
328	278,309,316,321,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	90,80,	0,0,	T,F,T,F,
340	295,321,333,309,	cylinder	--	--	--	--	--	--	--	--	--	--
371	316,352,359,364,	toroidal	10	0	70	0	circle,circle,circle,circle,	20,10,20,10,	0,9,0,9,	80,70,60,70,	0,17,0,17,	T,T,T,T,
383	333,364,376,352,	toroidal	--	--	--	--	--	--	--	--	--	--
409	359,390,397,402,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	60,40,	0,0,	T,F,T,F,
421	376,402,414,390,	cylinder	--	--	--	--	--	--	--	--	--	--
452	397,433,440,445,	toroidal	10	0	40	0	circle,circle,circle,circle,	20,10,10,10,	0,4,0,4,	40,40,30,40,	0,8,0,8,	T,F,T,F,
464	414,445,457,433,	toroidal	--	--	--	--	--	--	--	--	--	--
495	440,476,483,488,	cylinder	10	0	80	0	circle,line,circle,line,	10,10,	0,0,	30,20,	0,0,	T,F,T,F,
507	457,488,500,476,	cylinder	--	--	--	--	--	--	--	--	--	--
538	483,519,526,531,	toroidal	10	0	10	0	circle,circle,circle,circle,	10,10,20,10,	0,4,0,4,	20,10,10,10,	0,8,0,8,	T,F,T,F,
550	500,531,543,519,	toroidal	--	--	--	--	--	--	--	--	--	--
576	526,557,564,569,	cylinder	20	0	80	0	circle,line,circle,line,	20,20,	0,0,	10,0,	0,0,	T,F,T,F,
588	543,569,581,557,	cylinder	--	--	--	--	--	--	--	--	--	--
598	49,80,	plane	--	0	160	20	circle,circle,	20,20,	0,0,	160,160,	0,0,	T,T,
608	564,581,	plane	--	0	0	0	circle,circle,	20,20,	0,0,	0,0,	0,0,	T,T,

Fig.6.23 Output of the MAIN table for case study 2

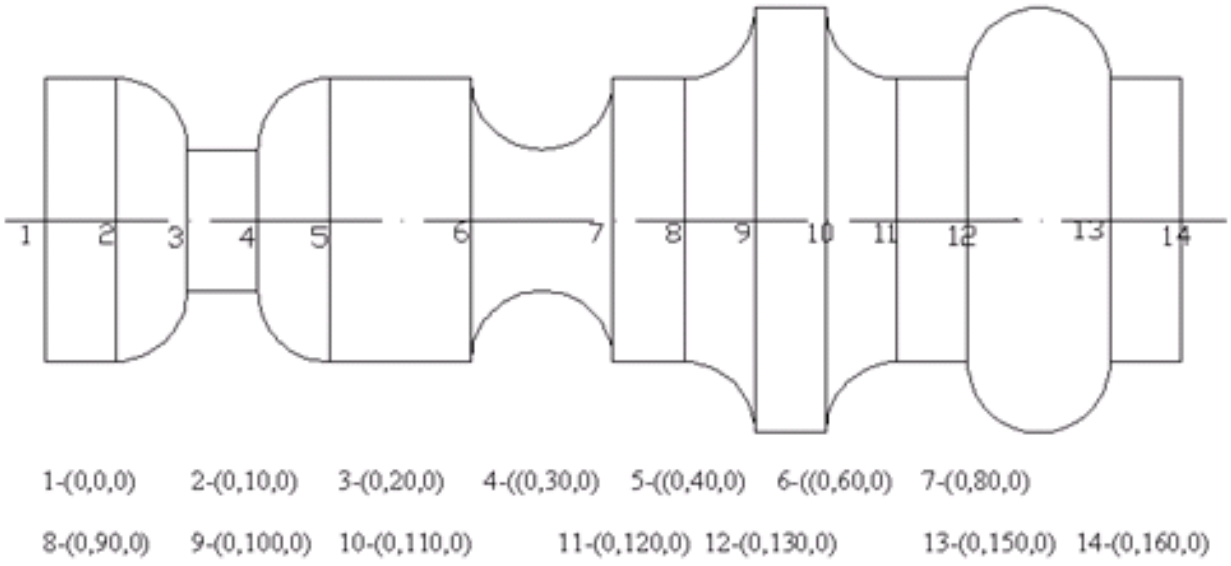


Fig. 6.24: Circle center coordinates for each cylinder of case study 2

Table 6.3: Summary output of the MAIN table for case study 2

A_F	E_C	Surface	E_C construction	Radius	X	Y	Z	T/F
75	49,56, 63,68,	cylinder	circle,line, circle,line,	20,20,	0,0,	160,150,	0,0,	T,F, T,F,
123	63,104, 111,116,	toroidal	circle,circle, circle,circle,	20,10, 20,10,	0,9, 0,9,	150,140, 130,140,	0,17, 0,17,	T,F, T,F,
161	111,142, 149,154,	cylinder	circle,line, circle,line,	20,20,	0,0,	130,120,	0,0,	T,F, T,F,
204	149,185, 192,197,	toroidal	circle,circle, circle,circle,	20,10, 30,10,	0,14, 0,14,	120,120, 110,120,	0,26, 0,26,	T,T, T,T,
247	192,228, 235,240,	cylinder	circle,line, circle,line,	30,30,	0,0,	110,100,	0,0,	T,F, T,F,
290	235,271, 278,283,	toroidal	circle,circle, circle,circle,	30,10, 20,10,	0,14, 0,14,	100,90, 90,90,	0,26, 0,26,	T,T, T,T,
328	278,309, 316,321,	cylinder	circle,line, circle,line,	20,20,	0,0,	90,80,	0,0,	T,F, T,F,
371	316,352, 359,364,	toroidal	circle,circle, circle,circle,	20,10, 20,10,	0,9, 0,9,	80,70, 60,70,	0,17, 0,17,	T,T, T,T,
409	359,390, 397,402,	cylinder	circle,line, circle,line,	20,20,	0,0,	60,40,	0,0,	T,F, T,F,
452	397,433, 440,445,	toroidal	circle,circle, circle,circle,	20,10, 10,10,	0,4, 0,4,	40,40, 30,40,	0,8, 0,8,	T,F, T,F,
495	440,476, 483,488,	cylinder	circle,line, circle,line,	10,10,	0,0,	30,20,	0,0,	T,F, T,F,
538	483,519, 526,531,	toroidal	circle,circle, circle,circle,	10,10, 20,10,	0,4, 0,4,	20,10, 10,10,	0,8, 0,8,	T,F, T,F,
576	526,557, 564,569,	cylinder	circle,line, circle,line,	20,20,	0,0,	10,0,	0,0,	T,F, T,F,

Table 6.4: Recognized cylinders for case study 2

A_F	Circle 1 center	Circle 2 center	Feature name	Radius	Length
75	(0,160,0)	(0,150,0)	Longitudinal cylinder	20	160-150=10
161	(0,130,0)	(0,120,0)	Longitudinal cylinder	20	130-120=10
247	(0,110,0)	(0,100,0)	Longitudinal cylinder	30	110-100=10
328	(0,90,0)	(0,80,0)	Longitudinal cylinder	20	90-80=10
409	(0,60,0)	(0,40,0)	Longitudinal cylinder	20	60-40=20
495	(0,30,0)	(0,20,0)	Longitudinal cylinder	10	30-20=10
576	(0,10,0)	(0,0,0)	Longitudinal cylinder	20	10-0=10

6.3.2 Recognition of Toroidal Feature

From Table 6.3 face (A_F) 123, surface (Surface column) is toroidal, E_C construction is circle, circle, circle, circle (let these circle names be circle 1, circle 2, circle 3, circle 4). Circle 2 and circle 4 radii are same, 10 (second and fourth values in radius column of table 6.3). From this it can be concluded as feature is toroidal of radius 10. Y coordinate for circle1 and circle 3 is decreasing from 150 to 130 (first and third values in y column of table 6.3) so, torus is external. Last column T/F indicates T, F, T, F, so, torus is convex in shape. For remaining faces (452, 538) is shown in Table 6.4. Same explanation continues for recognition of external concave toroidal features on faces 204,290,371 are shown in Table 6.5.

Table 6.5: Summary for external concave and convex toroidal feature

F.No.	**Circle 1, y1**	**Circle 3, y3**	**T/F**	**R2=R4**	**Radius**	**Length**
Convex toroidal feature						
123	150	130	T,F,T,F	10	10	150-130=20
452	40	30	T,F,T,F	10	10	40-30=10
538	20	10	T,F,T,F	10	10	20-10=10
Concave toroidal feature						
204	120	110	T,T,T,T	10	10	120-110=10
290	100	90	T,T,T,T	10	10	100-90=10
371	80	60	T,T,T,T	10	10	80-60=20

Note: F.No- Face Number; R2-Circle2 Radius; R4-Circle4 Radius;

6.4 CASE STUDY - 3

Figure 6.25 shows case study 3 drawing. It consists of seven features out of which two cylinders, four cylindrical holes and one blind inclined cross hole. All these features are recognized with the help of developed software. Dimensions for each feature are also recognized.

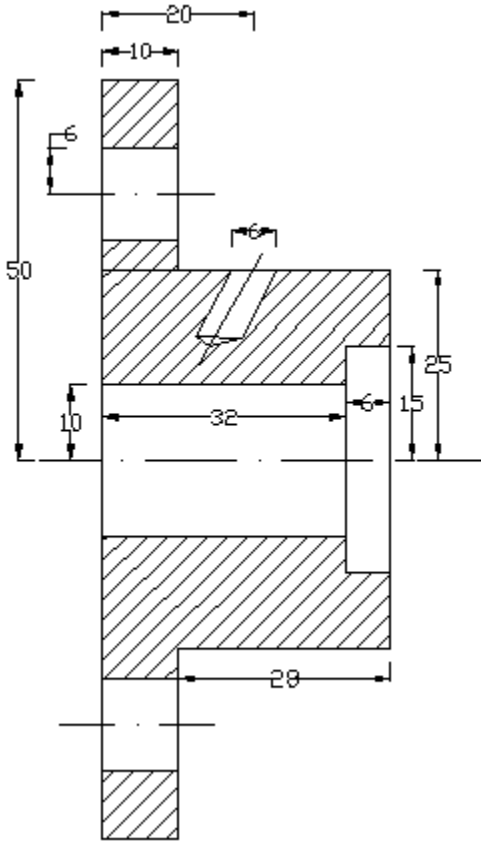
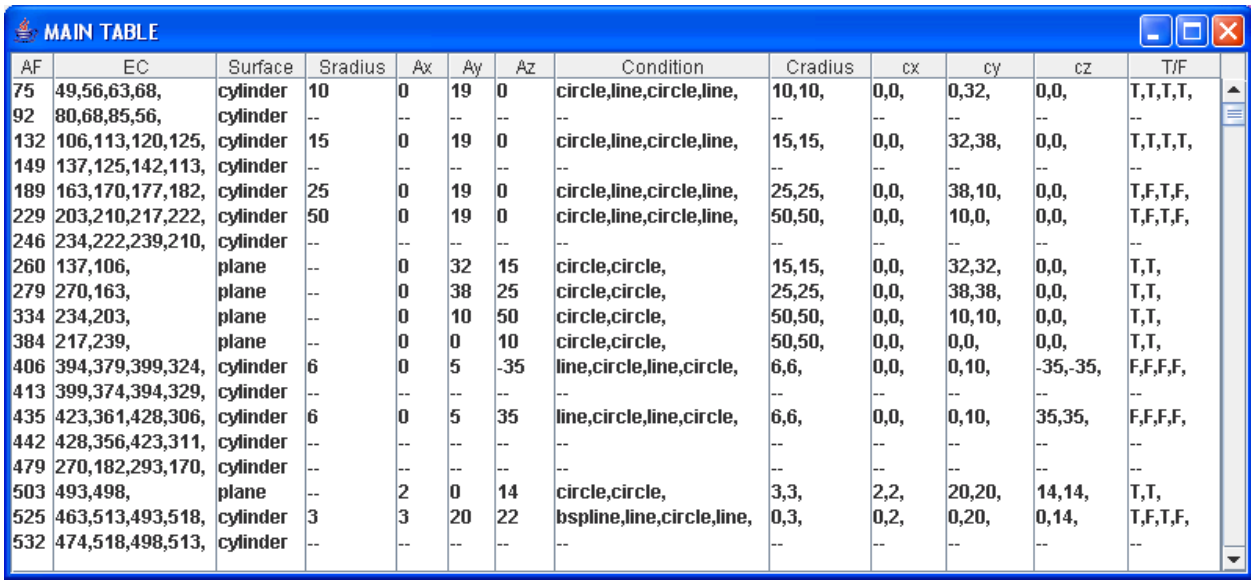


Fig. 6.25: Case study 3 drawing

6.4.1 Recognition of Cylindrical Hole - Online/Offline

From Table 6.6, Face (A_F) 75 axis z coordinate (AZ) is zero which indicates cylindrical hole is passing through axis. Face 406,435 axis z coordinates are -35 and 35 respectively. Negative sign indicates offset is below the axis otherwise offset is above the axis.



AF	EC	Surface	Sradius	Ax	Ay	Az	Condition	Cradius	cx	cy	cz	T/F
75	49,56,63,68,	cylinder	10	0	19	0	circle,line,circle,line,	10,10,	0,0,	0,32,	0,0,	T,T,T,T,
92	80,68,85,56,	cylinder	--	--	--	--	--	--	--	--	--	--
132	106,113,120,125,	cylinder	15	0	19	0	circle,line,circle,line,	15,15,	0,0,	32,38,	0,0,	T,T,T,T,
149	137,125,142,113,	cylinder	--	--	--	--	--	--	--	--	--	--
189	163,170,177,182,	cylinder	25	0	19	0	circle,line,circle,line,	25,25,	0,0,	38,10,	0,0,	T,F,T,F,
229	203,210,217,222,	cylinder	50	0	19	0	circle,line,circle,line,	50,50,	0,0,	10,0,	0,0,	T,F,T,F,
246	234,222,239,210,	cylinder	--	--	--	--	--	--	--	--	--	--
260	137,106,	plane	--	0	32	15	circle,circle,	15,15,	0,0,	32,32,	0,0,	T,T,
279	270,163,	plane	--	0	38	25	circle,circle,	25,25,	0,0,	38,38,	0,0,	T,T,
334	234,203,	plane	--	0	10	50	circle,circle,	50,50,	0,0,	10,10,	0,0,	T,T,
384	217,239,	plane	--	0	0	10	circle,circle,	50,50,	0,0,	0,0,	0,0,	T,T,
406	394,379,399,324,	cylinder	6	0	5	-35	line,circle,line,circle,	6,6,	0,0,	0,10,	-35,-35,	F,F,F,F,
413	399,374,394,329,	cylinder	--	--	--	--	--	--	--	--	--	--
435	423,361,428,306,	cylinder	6	0	5	35	line,circle,line,circle,	6,6,	0,0,	0,10,	35,35,	F,F,F,F,
442	428,356,423,311,	cylinder	--	--	--	--	--	--	--	--	--	--
479	270,182,293,170,	cylinder	--	--	--	--	--	--	--	--	--	--
503	493,498,	plane	--	2	0	14	circle,circle,	3,3,	2,2,	20,20,	14,14,	T,T,
525	463,513,493,518,	cylinder	3	3	20	22	bspline,line,circle,line,	0,3,	0,2,	0,20,	0,14,	T,F,T,F,
532	474,518,498,513,	cylinder	--	--	--	--	--	--	--	--	--	--

Fig.6.26: Output of the MAIN table for case study 3

Table 6.6: Summary output of the MAIN table for case study 3

A_F	Surface	AX	AY	AZ	E_C construction	CX	CY	CZ
75	cylinder	0	19	0	circle,line,circle,line,	0,0,	0,32,	0,0,
132	cylinder	0	19	0	circle,line,circle,line,	0,0,	32,38,	0,0,
189	cylinder	0	19	0	circle,line,circle,line,	0,0,	38,10,	0,0,
229	cylinder	0	19	0	circle,line,circle,line,	0,0,	10,0,	0,0,
406	cylinder	0	5	-35	line,circle,line,circle,	0,0,	0,10,	-35,-35,
435	cylinder	0	5	35	line,circle,line,circle,	0,0,	0,10,	35,35,
525	cylinder	3	20	22	bspline,line,circle,line,	0,2,	0,20,	0,14,

Note: AX, AY, AZ – Axis coordinates

6.4.2 Recognition of Blind Cross Hole and Inclination

Table 6.6 shows face 525 E_C construction column is bspline, line, circle, line. Which indicates blind cross hole (circle existence in E_C construction). Coordinates corresponding to line1 are obtained from FOB vertex table. Line is constructed by two points (p1-461 and p2-491).

Corresponding coordinates are p1 (4.34, 17, 24.62) and p2 (2.6, 17, 14.77). it is observed that y coordinate is same. The inclination is found using the following formula:

$$\text{Tan } \alpha = (x2 - x1) / (z2 - z1)$$

$$\text{Tan } \alpha = (2.6 - 4.34) / (14.77 - 24.62)$$

$$\alpha = 10.01793^0$$

Figure 6.27 shows recognized features for case study 3. The output of the case study 3 is shown in Figure 6.28.

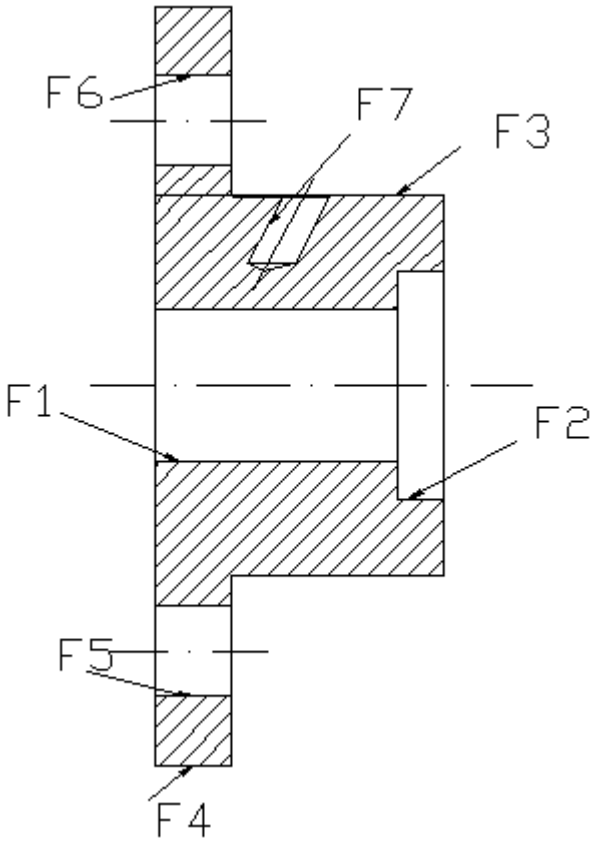
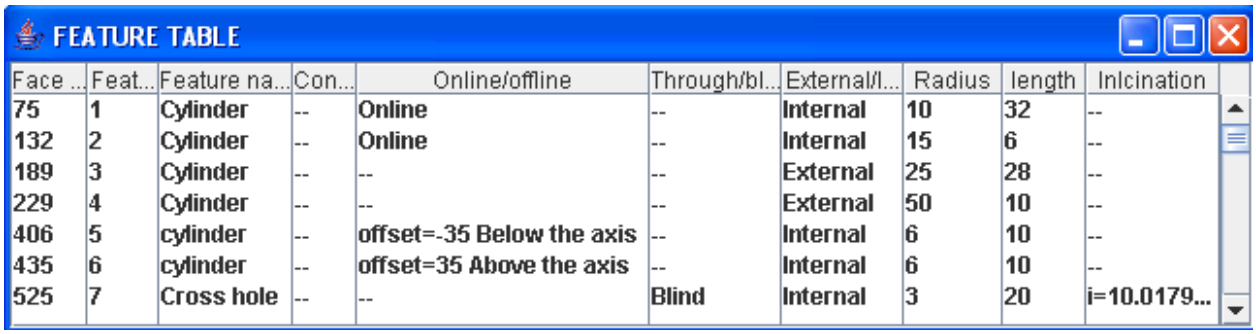


Fig. 6.27: Case study 3 with recognized features



Face ...	Feat...	Feature na...	Con...	Online/offline	Through/bl...	External/I...	Radius	length	Inlcination
75	1	Cylinder	--	Online	--	Internal	10	32	--
132	2	Cylinder	--	Online	--	Internal	15	6	--
189	3	Cylinder	--	--	--	External	25	28	--
229	4	Cylinder	--	--	--	External	50	10	--
406	5	cylinder	--	offset=-35 Below the axis	--	Internal	6	10	--
435	6	cylinder	--	offset=35 Above the axis	--	Internal	6	10	--
525	7	Cross hole	--	--	Blind	Internal	3	20	i=10.0179...

Fig. 6.28: Output of case study 3

In this chapter three case studies feature recognition procedure is explained. Four typical component results are presented in APPENDIX - C.

Chapter - 7

CONCLUSIONS AND FUTURE SCOPE OF WORK

CHAPTER - VII

CONCLUSIONS AND FUTURE SCOPE OF WORK

A detailed review of the existing literature has been carried out to identify the objective and scope of the present research. The review of literature points out that no significant amount of work has been done to extract features from the STEP file for rotational parts.

7.1 CONCLUSIONS

In the present investigation, an attempt has been made to design and develop a software that is capable of extracting geometrical data from STEP file and feature recognition with parameters. The developed program can be applied to auxiliary industrial parts like shafts, spindles, axles etc. The software facilitates the extraction of features like cylindrical, conical, with external and internal features, curved, cross hole features, slot and keyway features. In order to develop fully an automated system starting from STEP file to feature recognition without any human intervention, five modules are developed – namely i) geometric data extraction module ii) cylindrical feature module iii) curvature feature module iv) cross hole feature module and v) special feature module. The algorithms proposed in this work are coded in Java and can be executed on any IBM or its compatible computers.

In short, an attempt has been made to present to the manufacturing world, a new technology, "STEP to Feature". For CAD/CAM integration, the key idea here is the use of STEP file as the driving constraint in feature recognition and thereby giving it as an input to Computer Aided Process Planning (CAPP).

7.2 SCOPE FOR FUTURE RESEARCH

- This thesis works for only rotational components. It can be extended for prismatic components to make the program much more comprehensive.
- The feature recognizer can be upgraded in the future to recognize features like gears, spline-shafts, knurling, multi-start threads features etc.
- Utilizing various features from feature recognizer process plans can be prepared.
- Further, process plans can be optimized.