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Mathematics and Computers

MASTER

COMPENSATING TOOL-PATH DATA IN
NUMERICAL CONTROL
MACHINE TAPES

T. W. Bookhart
R. J. Easterday

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the ATOMIC ENERGY COMMISSION under U. S. GOVERNMENT Contract W-7405 eng 26

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Nuclear Division

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CONTROL MACHINE TAPES

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ABSTRACT

A computer routine for making adjustments to two-dimensional tool path data has been incorporated into the APT system as a preprocessor. The routine reads the cutter location tape (CLTAPE), makes specified adjustments to the cutter center data, and creates a new CLTAPE for use by the machine postprocessor.

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SUMMARY

A computer routine for making adjustments or compensations to tool path data has been incorporated into the APT system. This routine, which functions like a preprocessor, reads the cutter location tape (CLTAPE), makes adjustments to the cutter center data, and creates a new CLTAPE for the machine postprocessor. The added capability is for parts which are defined in two dimensions and will be applicable for tapes for turning machines as well as templates.

The compensations can be applied in a direction normal to the surface, radially, or in the direction of X or Y only. The adjustments are specified at locations along the part contour by a specially created APT word, CLCOMP. Compensations between specified locations are computed in the preprocessor using linear interpolation of adjustment versus surface arc length.

INTRODUCTION

Oftentimes the need arises to make adjustments or compensations to tool-path data in numerical control (N/C) machine-part tapes. Making such compensations can be a most unhandy, time-consuming task for a part programmer. In order to facilitate the making of tape compensations, a capability has been added to the APT system at the Oak Ridge Y-12 Plant.^(a) With this capability, a part programmer can conveniently make compensations to the tool-path data appearing in the N/C punched tape. The added capability is for parts which are defined in two dimensions and will be applicable to tapes for turning machines as well as templates.

In cases where tape-data compensation is desired, adjustment values are specified at specific locations along the contour of the part. The cutter path, as appearing in the N/C punched tape, is to be altered by a specified amount at the given point on the part. What adjustments to make, if any, between the specified locations is generally vague and often left to the discretion of the part programmer. Having an APT capability for adjusting tape data provides a well-defined method of determining and applying compensations between the specified data points.

(a) Operated for the US Atomic Energy Commission by the Union Carbide Corporation-Nuclear Division.

COMPENSATING THE TOOL-PATH DATA

METHOD

The desired compensations are applied to the cutter-center data as computed in the APT system, before the cutter-center information is passed along to the machine postprocessor to make the punched tape. This provision is accomplished by creating what has been termed an "APT preprocessor". This preprocessor reads the cutter location tape (CLTAPE), makes adjustments to the cutter-center data, and creates a new CLTAPE for use by the machine postprocessor. The flow is as shown in Figure 1. The preprocessor, like any other postprocessor, is called by a MACHIN statement and only applies in part programs in which this statement appears.

Figure 1. PROGRAM FLOW.

Interpolation Between Data Points

The specified compensations are applied to the cutter-center data at the specified data points. At intermediate cutter-center points, compensations are calculated and applied to those cutter centers. This calculation is based on linear interpolation of compensations at the given data points versus surface arc length between the data points. This arc length between data points is calculated in the preprocessor as the sum of the lengths of the cut vectors between the data points. (That is, the arc length used in the calculation is the distance the cutter travels between data points.) Figure 2 illustrates this interpolation.

Figure 2. COMPENSATION INTERPOLATION.

Applying Compensations

The compensations can be applied in a direction normal to the surface, radially, or in the direction of X or Y only. The amount and method of application is specified in a specially created part-program instruction, CLCOMP. The complete instruction is:

```

                                NORMAL
                                RADIUS
                                RIGHT
CLCOMP/LEFT,n,ADJUST,XCOORD .
                                OFF
                                YCOORD
  
```

Here, RIGHT and LEFT refer to the direction in which a positive compensation will be applied, n is the specified compensation to be applied (in inches), and the final parameter states in which manner the adjustment is to be applied. Adjustment normal to the surface will be assumed unless specified otherwise. For offsetting normally, the preprocessor computes the normal vector as that vector which bisects the angle made by the cut vectors to and away from the point to be compensated (see Figure 3).

Figure 3. COMPUTED NORMAL VECTOR.

The adjustments described here are always applied to cutter-center data which are computed by the APT system using linear interpolation of the machine axes. For the case where the contour (or a portion of the contour) is a circle and circular interpolation could be used by the machine control, the preprocessor forces linear interpolation if compensations are specified.

PART PROGRAM

The part program utilizing the preprocessor is identical to an uncompensated program with the following exceptions:

1. A MACHIN statement for the preprocessor (MACHIN/COMPTR,MODIFY,CONTUR).
2. A check surface at each location where a compensation is to be defined. A CLCOMP statement will specify the adjustment to be applied here.

To avoid a discontinuity in the finished part, the value of the first and last compensation specified should be zero and the manner of application (eg, normal or radial) should be the same throughout.

Example

The part shown in Figure 4 was programmed as an illustrative example. Detailed computer information is contained in the Appendix, which includes: the part program, a listing of the uncompensated CLTAPE, the compensated CLTAPE, and the machine postprocessor listing.

Figure 4. ILLUSTRATIVE EXAMPLE.

APPENDIX

PART PROGRAM

PARTNO CLCOMP TEST NC T.W.B. 7-1-70	0101
CHARGE#4069	0102
MACHIN/COMPTR.MODIFY.CONTUR	0103
MACHIN/EXCELO.TURN.921	0104
XAX #LINE/0.0.10.0	0105
YAX #LINE/0.0.0.10	0106
ORIG #POINT/0.0.0	0107
CIR #CIRCLE/0.0.5	0108
TANPT #POINT/CIR.ATANGL.45	0109
L45 #LINE/TANPT.ATANGL.-45	0110
LDIA #LINE/5.0.5.10	0111
STRTOC#POINT/7.-3.0	0112
CK1 #LINE/0.-2.10.-2	0113
CK2 #LINE/0.-1.10.-1	0114
CK3 #LINE/0.0.10.0	0115
CK4 #LINE/0.1.10.1	0116
CK5 #LINE/ORIG.TANPT	0117
CK6 #LINE/ORIG.ATANGL.60	0118
CLPRNT	0119
CUTTER/.200	0120
FEDRAT/5.1PM	0121
FROM/STRTOC	0122
GO/TO.LDIA	0123
TLRGT	0124
GORGT/LDIA.ON.CK1	0125
CLCOMP/RIGHT.0.ADJUST.NORMAL \$\$ INITIAL VALUE#0	0201
GODLTA/0.1.0	0202
CLCOMP/RIGHT.-.010	0203
GODLTA/0.1.0	0204
CLCOMP/RIGHT..005	0205
GOFWD/LDIA.ON.CK4	0206
GOFWD/LDIA.PAST.L45	0207
CLCOMP/RIGHT.-.007	0208
GOLFT/L45.ON.CK5	0209
CLCOMP/RIGHT..010	0210
GOFWD/CIR.ON.CK6	0211
CLCOMP/RIGHT.-.010	0212
GOFWD/CIR.ON.YAX	0213
CLCOMP/OFF \$\$ FINAL VALUE#0	0214
GODLTA/0.1.0	0215
GODLTA/7.0.0	0216
GOTO/STRTOC	0217
REWIND/1	0218
STOP	0219
END	0220
FINI	0221

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LISTING OF UNCOMPENSATED CLTAPE

CLCOMP TEST OC T.W.B. 7-1-70	CLCOMP/ RIGHT -0.0070	CLCOMP/ OFF
MACHIN/COMPTR MODIFY 0.0	DS IS/ 1.45	DS IS
MACHIN/EXCELD TURN 921.0	X Y Z 3.606245 3.606245 0.	X Y Z 0. 6.100500 0.
CUTTER/ 0.2000	CLCOMP/ RIGHT 0.0100	DS IS
FEDRAT/ 5.0000 IPM	CIR(0) # CIRCLE/ 0. 0. 0. 5.0000	X Y Z 7.000000 6.100500 0.
FROM /STRTOC	DS IS/ CIR	DS IS/STRTOC
X Y Z 7.000000 -3.000000 0.	X Y Z 3.555745 3.656744 0. 3.453729 3.753246 0. 3.349095 3.846903 0. 3.241922 3.937644 0. 3.132292 4.025400 0. 3.020287 4.110105 0. 2.905994 4.191694 0. 2.789497 4.270105 0. 2.670886 4.345280 0. 2.550250 4.417162 0.	X Y Z 7.000000 -3.000000 0.
DS IS/ LDIA		REWIND/ 1.0000
X Y Z 5.100000 -3.000000 0.		STOP
TOOL IS(RIGHT)		END
DS IS/ LDIA		FINI
X Y Z 5.100000 -2.000000 0.		
CLCOMP/ RIGHT 0. ADJUST NORMAL	CLCOMP/ RIGHT -0.0100	
DS IS	CIR(0) # CIRCLE/ 0. 0. 0. 5.0000	
X Y Z 5.100000 -1.000000 0.	DS IS/ CIR	
CLCOMP/ RIGHT -0.0100	X Y Z 2.425572 4.486836 0. 2.301132 4.551911 0. 2.174947 4.613535 0. 2.047114 4.671661 0. 1.917729 4.726247 0. 1.786891 4.777250 0. 1.654697 4.824632 0. 1.521250 4.868356 0. 1.386650 4.908390 0. 1.250998 4.944704 0. 1.114398 4.977269 0. 0.976953 5.006061 0. 0.838768 5.031059 0. 0.699947 5.052243 0. 0.560595 5.069598 0. 0.420819 5.083109 0. 0.280723 5.092767 0. 0.140415 5.098565 0. 0. 5.100500 0.	
DS IS		
X Y Z 5.100000 -0. 0.		
CLCOMP/ RIGHT 0.0050		
DS IS/ LDIA		
X Y Z 5.100000 1.000000 0.		
DS IS/ LDIA		
X Y Z 5.100000 2.112489 0.		

LISTING OF COMPENSATED CLTAPE

CLCOMP TEST OC T.W.B. 7-1-70			
MACHIN/EXCELO TURN 921.0			
CUTTER/ 0.2000			
FEDRAT/ 5.0000 IPM			
FROM /STRTOC			
	X	Y	Z
	7.000000	-3.000000	0.
DS IS/ LDIA			
	X	Y	Z
	5.100000	-3.000000	0.
TOOI IS(RIGHT)			
DS IS/ LDIA			
	X	Y	Z
	5.100000	-2.000000	0.
CLCOMP/ RIGHT. +0000000 ADJUST NORMAL			
DS IS			
	X	Y	Z
	5.090000	-1.000000	-0.
CLCOMP/ RIGHT -0.01000			
DS IS			
	X	Y	Z
	5.105000	-0.	0.
CLCOMP/ RIGHT +0.00500			
DS IS/ LDIA			
	X	Y	Z
	5.099320	1.000000	-0.
DS IS/ LDIA			
	X	Y	Z
	5.093533	2.109810	-0.
CLCOMP/ RIGHT -0.00700			
DS IS/ 1.45			
	X	Y	Z
	3.613316	3.613316	0.
CLCOMP/ RIGHT +0.01000			
DS IS/ CIR			

	X	Y	Z
	3.561971	3.663146	0.
	3.458351	3.758270	0.
	3.352196	3.850466	0.
	3.243587	3.939667	0.
	3.132609	4.025808	0.
	3.019348	4.108826	-0.
	2.903891	4.188661	-0.
	2.786328	4.265255	-0.
	2.666751	4.338553	-0.
	2.545251	4.408502	-0.
CLCOMP/ RIGHT -0.01000			
DS IS/ CIR			
	X	Y	Z
	2.421070	4.478510	-0.
	2.297099	4.543933	-0.
	2.171360	4.605924	-0.
	2.043948	4.664437	-0.
	1.914961	4.719425	-0.
	1.784496	4.770847	-0.
	1.652650	4.818663	-0.
	1.519525	4.862835	-0.
	1.385220	4.903330	-0.
	1.249837	4.940116	-0.
	1.113479	4.973164	-0.
	0.976248	5.002449	-0.
	0.838249	5.027947	-0.
	0.699586	5.049639	-0.
	0.560364	5.067507	-0.
	0.420689	5.081537	-0.
	0.280665	5.091717	-0.
	0.140401	5.098040	-0.
	-0.000000	5.100500	-0.
CLCOMP/ OFF			
DS IS			
	X	Y	Z
	0.	6.100500	0.
DS IS			
	X	Y	Z
	7.000000	6.100500	0.
DS IS/STRTOC			
	X	Y	Z
	7.000000	-3.000000	0.
REWIND/ 1.0000			
STOP			
END			
FINI			

POSTPROCESSOR LISTING

POSTPROCESSOR OUTPUT FOR BENDIX DYNAPATH 1800						
PARTNO CLCOMP TEST OC T.W.B. 7-1-70						
MACHIN/EXCELO. TURN. 921						
TAPE BLOCK	RPM	FEED RATE	TAPE BLOCK	MACHINE TIME	TAPE MIN LENGTH	
X-COORD # 7.00000 Y-COORD # -3.00000						
N001G0IX-190000F26\$		5.0000	1	0.4		
N002F15000\$		0.	2	0.4		
X-COORD # 5.10000 Y-COORD # -3.00000						
N003Y100000F50\$		5.0000	3	0.6		
X-COORD # 5.10000 Y-COORD # -2.00000						
PPRINT CLCOMP/ RIGHT. +0000000	ADJUST	NORMAL				
N004X-1000Y100000F50\$		5.0000	4	0.8		
X-COORD # 5.09000 Y-COORD # -1.00000						
PPRINT CLCOMP/ RIGHT -0.01000		5.0000	5	1.0		
N005X1500Y100000F50\$						
X-COORD # 5.10500 Y-COORD # -0.						
PPRINT CLCOMP/ RIGHT +0.00500		5.0000	6	1.2		
N006X-568Y100000F50\$						
X-COORD # 5.09932 Y-COORD # 1.00000		5.0000	7	1.4		
N007X-578Y110982F45\$		0.	8	1.4		
N008F15000\$						
X-COORD # 5.09354 Y-COORD # 2.10982						
PPRINT CLCOMP/ RIGHT -0.00700		5.0000	9	1.8		
N009X-148022Y150350F24\$						
X-COORD # 3.61332 Y-COORD # 3.61332						
PPRINT CLCOMP/ RIGHT +0.01000		5.0000	10	1.8		
N010X-5134Y4982F699\$		5.0000	11	1.9		
N011X-10362Y9512F355\$		5.0000	12	1.9		
N012X-10616Y9220F356\$		5.0000	13	1.9		
N013X-10862Y8920F356\$		5.0000	14	2.0		
N014X-11098Y8614F356\$		5.0000	15	2.0		
N015X-11326Y8302F356\$		5.0000	16	2.0		
N016X-11544Y7984F356\$		5.0000	17	2.0		
N017X-11758Y7660F356\$		5.0000	18	2.1		
N018X-11956Y7330F357\$		5.0000	19	2.1		
N019X-12150Y6994F357\$						
X-COORD # 2.54526 Y-COORD # 4.40850						
PPRINT CLCOMP/ RIGHT -0.01000		5.0000	20	2.1		
N020X-12420Y7002F351\$		5.0000	21	2.1		
N021X-12396Y6542F357\$		5.0000	22	2.2		
N022X-12574Y6198F357\$		5.0000	23	2.2		
N023X-12742Y5852F357\$		5.0000	24	2.2		
N024X-12898Y5498F357\$		5.0000	25	2.3		
N025X-13046Y5142F357\$		5.0000	26	2.3		
N026X-13184Y4782F357\$		5.0000	27	2.3		
N027X-13314Y4418F356\$		5.0000	28	2.3		
N028X-13430Y4048F356\$		5.0000	29	2.4		
N029X-13538Y3680F356\$		5.0000	30	2.4		
N030X-13636Y3304F356\$		5.0000	31	2.4		
N031X-13724Y2928F356\$		5.0000	32	2.5		
N032X-13800Y2550F356\$						

POSTPROCESSOR OUTPUT FOR BENDIX DYNAPATH 1800						
PARTNO CLCOMP TEST OC T.W.B. 7-1-70						
MACHIN/EXCELO. TURN. 921						
TAPE BLOCK	RPM	FEED RATE	TAPE BLOCK	MACHINE TIME	TAPE MIN LENGTH	
N033X-13866Y2170F356\$		5.0000	33	2.5		
N034X-13922Y1786F356\$		5.0000	34	2.5		
N035X-13968Y1404F356\$		5.0000	35	2.5		
N036X-14002Y1018F356\$		5.0000	36	2.6		
N037X-14026Y632F356\$		5.0000	37	2.6		
N038X-14040Y246F356\$		5.0000	38	2.6		
N039F15000\$		0.	39	2.6		
X-COORD # -0. Y-COORD # 5.10050						
PPRINT CLCOMP/ OFF		5.0000	40	2.8		
N040Y100000F50\$		0.	41	2.8		
N041F15000\$						
X-COORD # 0. Y-COORD # 6.10050						
N042X700000F7\$		5.0000	42	4.3		
N043F15000\$		0.	43	4.3		
X-COORD # 7.00000 Y-COORD # 6.10050						
N044Y-910050F5\$		5.0000	44	6.3		
N045F15000\$		0.	45	6.3		
X-COORD # 7.00000 Y-COORD # -3.00000						
N046M30\$		0.	46	6.3		
REWIND 7.00000 -3.00000				6.3	9.2FT	
N047M00\$		0.	47	6.3		
STOP 7.00000 -3.00000				6.3	9.2FT	
N048M02\$		0.	48	6.3		
END 7.00000 -3.00000				6.3	9.3FT	
				6.3	21.3FT	