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A general algorithm for profiling and dressing grinding wheels when using a grinding spindle on a CNC lathe

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Remarkable progress is being made in the technology for grinding complicated geometrical parts. Today, some factories are considering adding a grinding spindle to a turning lathe to save buying an additional expensive new grinding machine. The grinding spindle will be interchangeable with a turning boring bar and it will need two types of software. First is a program and subroutine to control the machine movement during the grinding profile of the work-piece. Second a program and a subroutine are needed to profile the new grinding wheels according to the grinding profiles of the work-piece, as well as dressing the grinding wheels after usage. In the case of a very small depth of cut, a long program will be required. Each different shape of grinding wheel will require different software. There are no detailed descriptions for this problem in the literature or machine manuals. This paper presents a general algorithm to make the profiling and dressing programs for grinding wheels easier. The programmer will use this algorithm for creating a subroutine suitable for the machine dressing system. This algorithm can be used on grinding machines as well as on an additional grinding spindle on a hollow spindle lathe. This subroutine will be used for profiling and dressing the most common shape of grinding wheels. The programmer will then only need to fill in the parameters which describe the contour of the grinding wheels. This algorithm has been applied on a hollow spindle lathe equipped with a numerical Sinumeric 840C control. Several grinding wheels have been profiled and dressed using the proposed approaches, and satisfactory results were obtained.

1. Introduction

Grinding operations have been necessary for many engineering applications, particularly in parts needing a good surface finish. CNC grinding applications became a challenging job with the increased use of parts with complex geometry. However the cost of machining on CNC grinding machines is high when they are only used for low or medium production runs (Luggan 1983, Groover and Zimmers 1984, Siemens 1999a, 1999b).

There are several challenges when adding the grinding spindle to a CNC lathe. The main concern is the control software. The 'add on' can be very long and complicated (Abbas 2003). Also a different type of software will be needed; i.e. software for profiling new grinding wheels as well as dressing of old grinding wheels. There are no detailed descriptions in the literature or machine manuals.

In this paper a general algorithm has been created and can be applied on any modern CNC machine. It is used to generate a subroutine for profiling new grinding wheels and dressing old grinding wheels, as well as setting zero offsets. This

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subroutine has been applied on a hollow spindle lathe equipped with a numerical control Sinumeric 840C. A subroutine (SPF49) for different profiles of grinding wheels is created. These grinding wheels are used for grinding the different finish zones in the combustion chamber of large gun barrel.

2. General algorithm

The following is a general algorithm suitable for creating a subroutine for use on any modern type of CNC control. This algorithm and the algorithm addressed by the author (Abbas 2003) represents a complete solution for adding on a grinding spindle on a hollow spindle lathe. The main concept of this algorithm is putting all complicated formula calculations, which are needed in the profiling and dressing operations, as well as machine movements, in parametric form. This algorithm explains in very clear statements the method of creating a subroutine for profiling and dressing taper shape grinding wheels as well as setting offsets in the X and Z axes. In this algorithm the programmer should input the distance from machine centre to the diamond position, as well as the distance from the face-plate to the diamond position. The programmer will input the geometrical parameters for the grinding wheels as well as the cutting condition for the profiling operation, and the subroutine will make all necessary calculations for profiling and dressing operations. The algorithm contains all necessary messages for wrong input to prevent machine crashes. The subroutine can be used for profiling and dressing up to four grinding wheels at the same setting. The programmer can increase the number of grinding wheels by changing the parameters values. These grinding wheels can be used for grinding the different zones in the combustion chamber of large gun barrel as well as complicated geometrical parts. The general algorithm is shown in figure 1.

3. Applications

The above algorithm was used to create a subroutine (SPF 49) suitable for the Sinumeric (840-C) control. The complete software for this subroutine is shown in Appendix A. After loading the subroutine into the CNC unit, the subroutine will be used in all profiling and dressing operations for all taper type grinding wheels as shown in figure 2.

The shape is described in parameters and the programmer can change the values of these parameters according to need. For example, if the programmer wants to profile four grinding wheels at the same setting, he should fill in the parameters for subroutines SPF 201, SPF 202, SPF 203 and SPF 204. In this subroutine the programmer will define the taper angle, the value of the connection arc and the partial length of the taper zone. A typical procedure is shown in figure 3 for subroutine SPF 201.

After storing the subroutines SPF 49 and SPF 201-204 in the CNC unit, the CNC unit will also need a program like MPF 51 to call out different subroutines which are used on profiling and dressing operation. This program also contains all cutting conditions for profiling and dressing operations. A typical program is shown in figure 4.

The above set-up was used for profiling and dressing four taper type grinding wheels with different profiles. They were used to finish the grinding zones of the combustion chamber for a large gun barrel, after the turning operation on the same machine. These grinding wheels are shown in figure 5. The time saving on preparing and testing the profiling and dressing program was almost 95%.

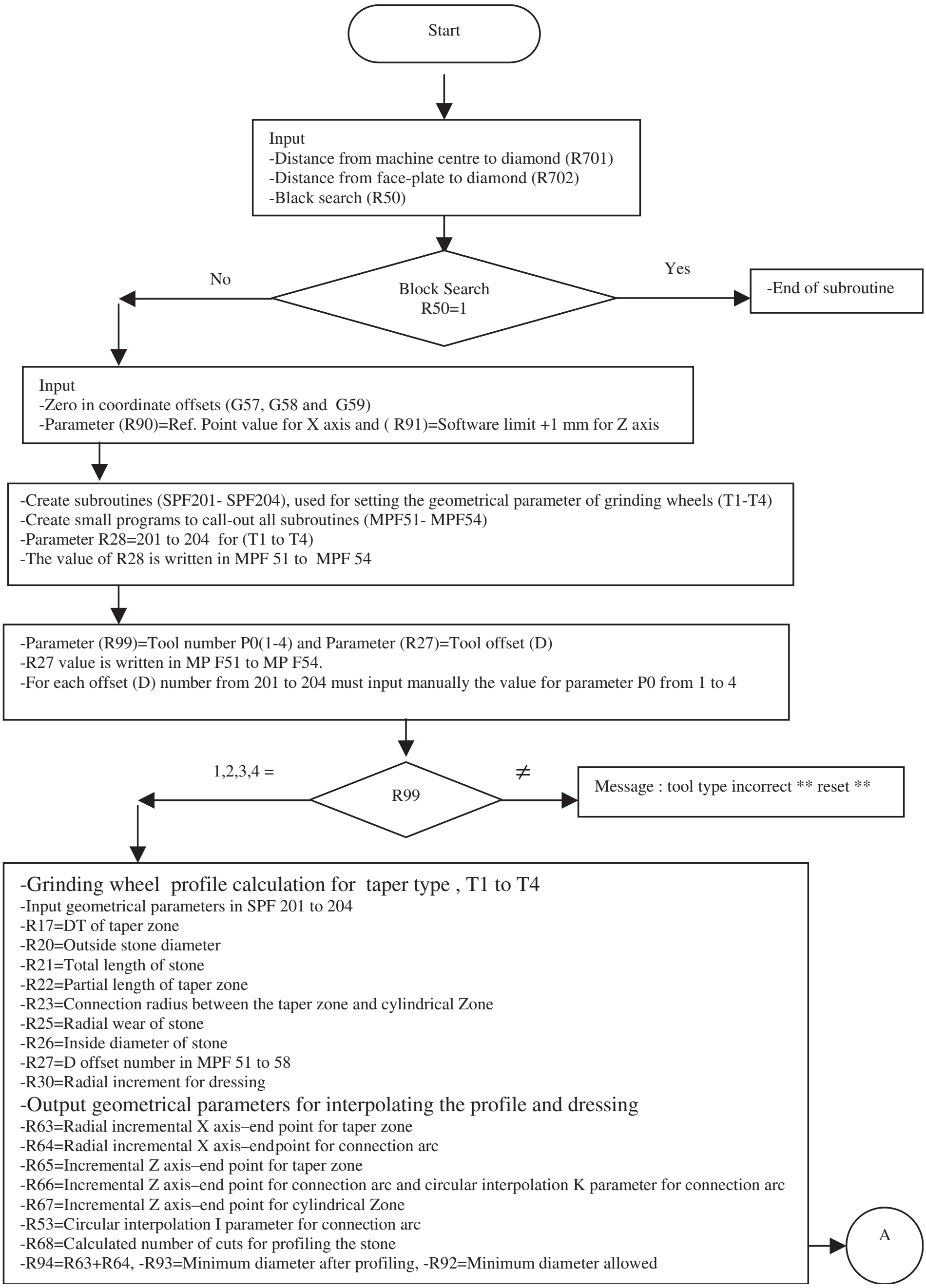

Figure 1. General algorithm for profiling and dressing grinding wheels.

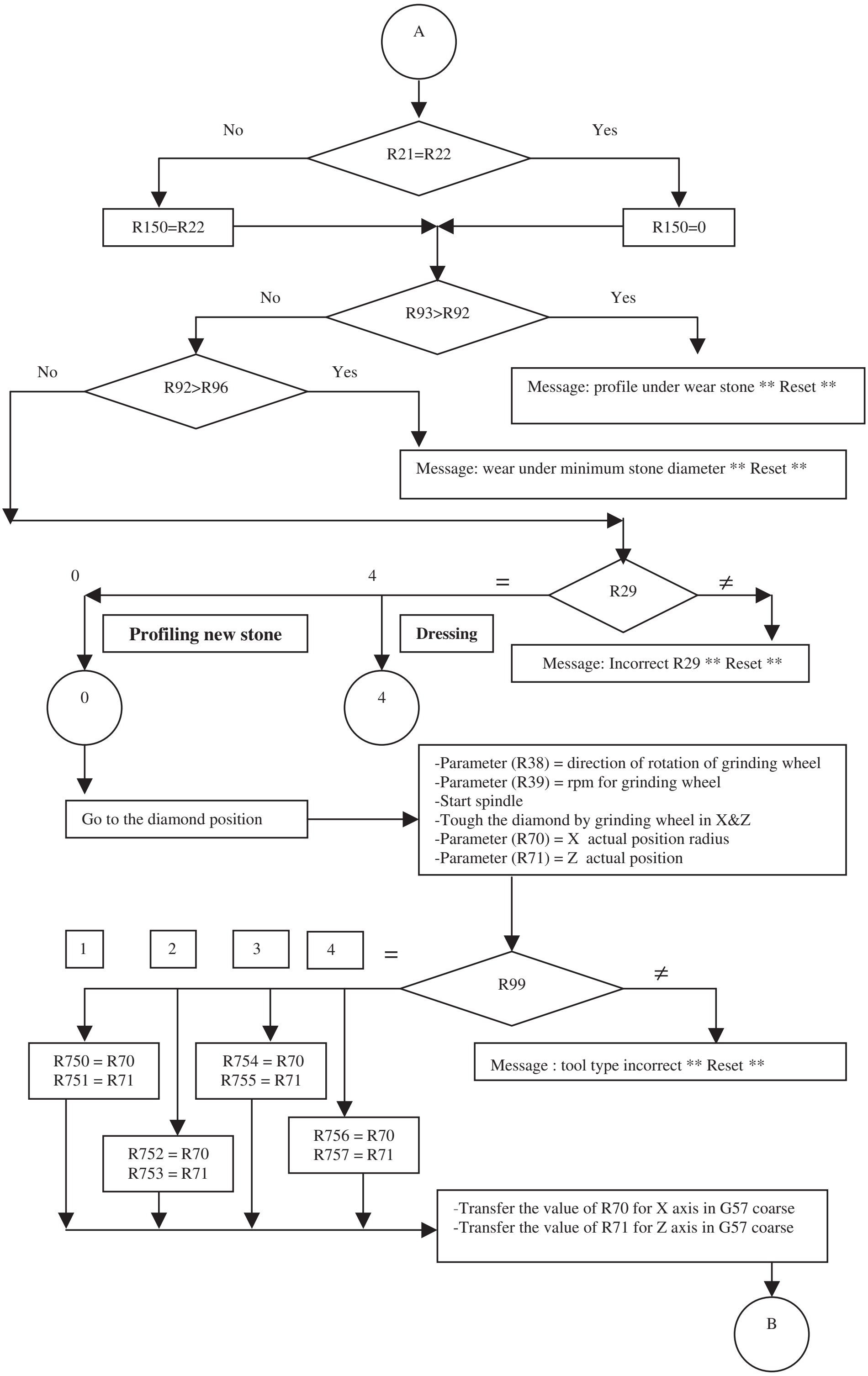

Figure 1. *Continued.*

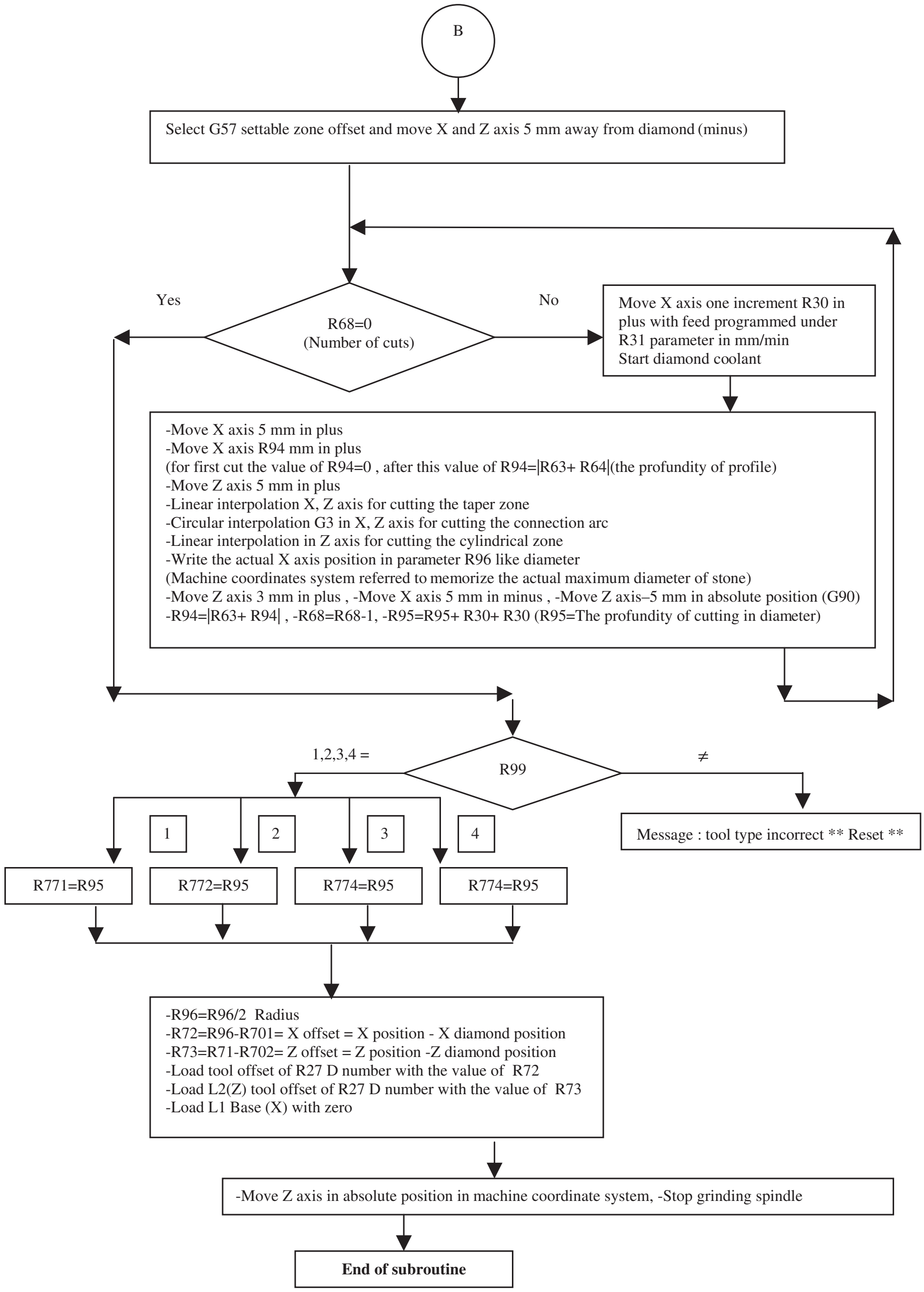

Figure 1. *Continued.*

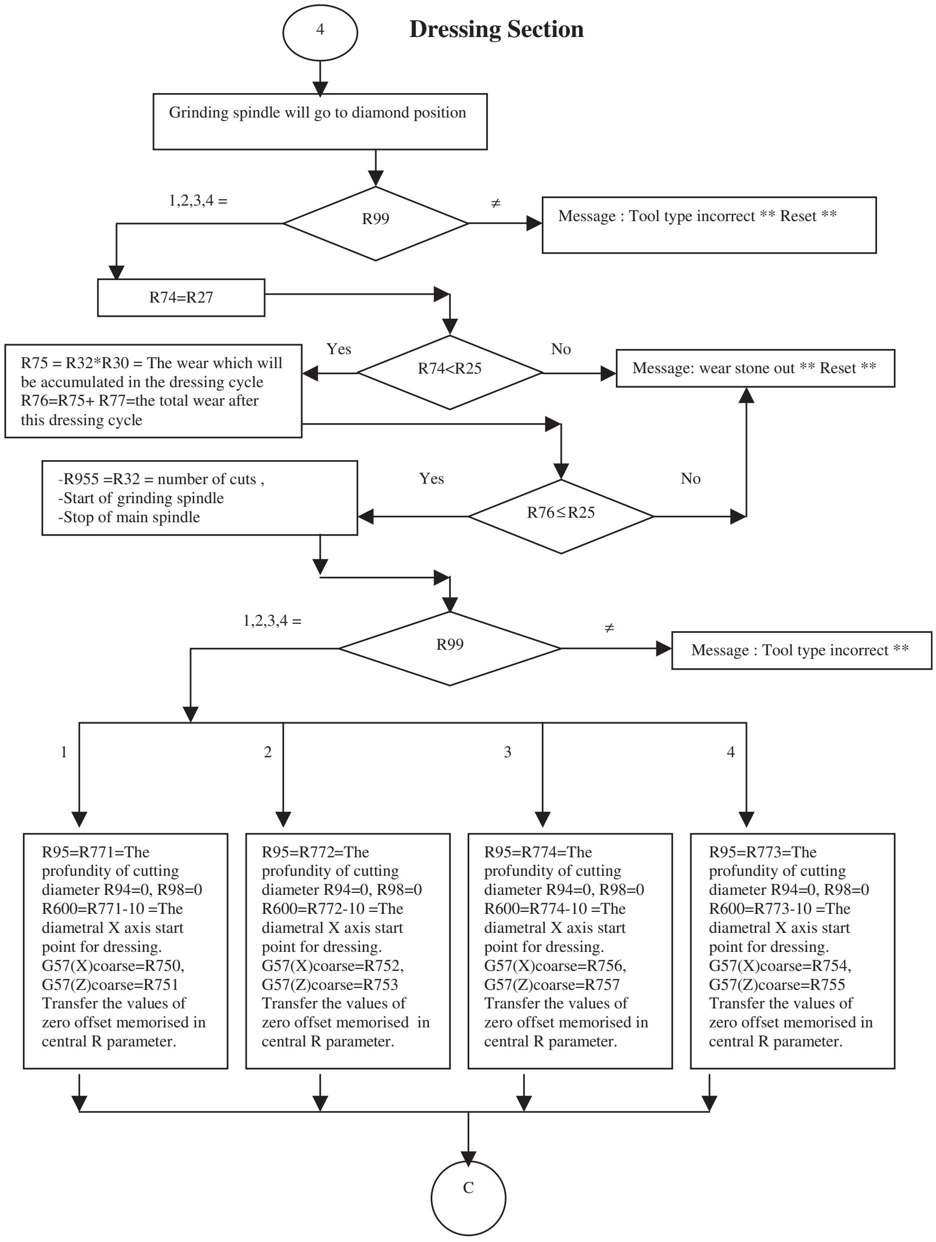

Figure 1. *Continued.*

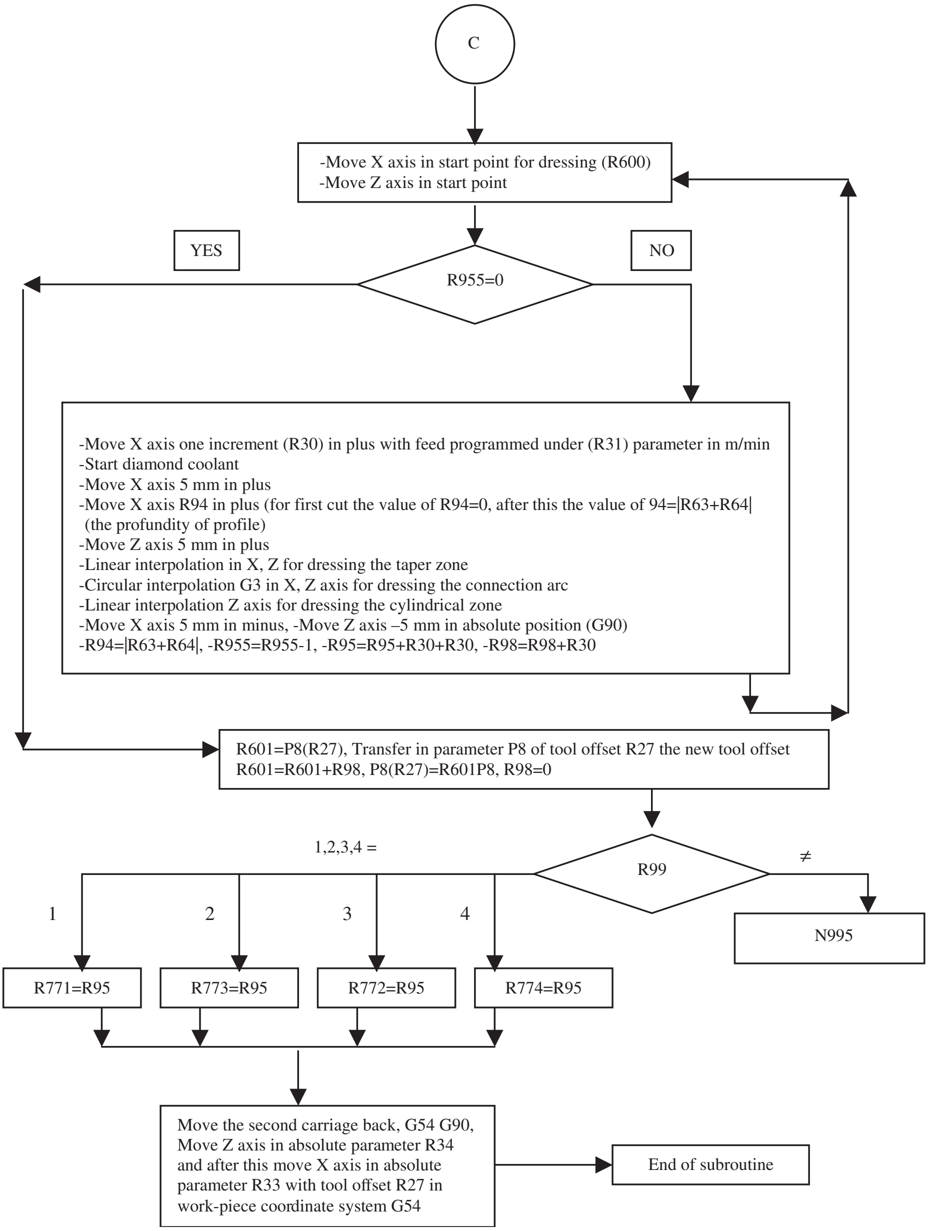

Figure 1. *Continued.*

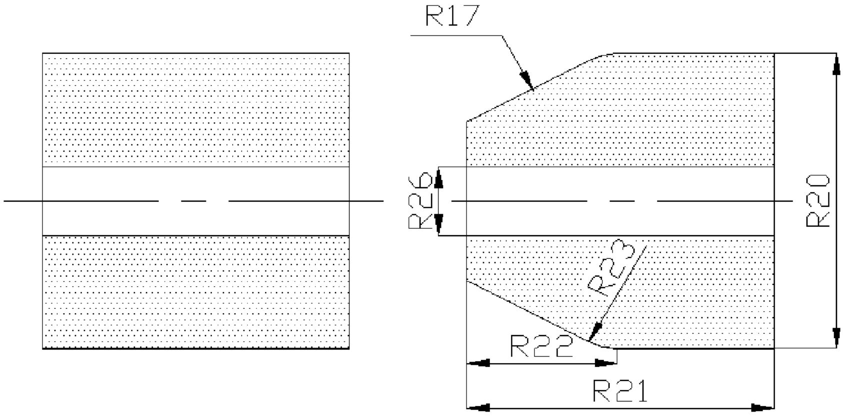

Figure 2. Grinding wheel before and after profiling.

```
% SPF 201
(TAPER TYPE GRINDING WHEEL - NUMBER 1)
(SUBROUTINE DESCRIBE STONE PROFILE)
R17=0.0285   (DT OF ANGLE)
R20=117.30   (OUTSIDE STONE DIAMETER)
R21=49       (TOTAL LENGTH OF STONE)
R22=44       (PARTIAL LENGTH OF STONE)
R23=20       (CONNECTION RADIUS)
R25=10       (RADIAL WEAR OF STONE)
R26=82       (INSIDE DIAMETER OF STONE)
R27=201      (D OFFSET NUMBER WITH T1)
M17
```

Figure 3. Subroutine SPF 201 describes the profile of the first grinding wheel.

```
% MPF 51
(USE THIS PROGRAM FOR PROFILING A NEW STONE OR TO DO)
(A INDEPENDENT DRESSING  CYCLE)
(TAPER TYPE -STONE NUMBER 1)
(PROGRAM FOR PROFILING A NEW STONE R29= 0 AND R30=0.040)
(PROGRAM FOR DRESSING THE STONE R29= 4 AND R30=0.003)
(OTHER VALUES REMAIN UNCHANGED)
R27=201      (STONE TOOL OFFSET)
R28=201      (SUBROUTINE NUMBER OF STONE PROFILE)
R29=4        (SELECT THE VALUE FOR YOUR JOB)
R30=0.020    (RADIAL INCREMENT TO DRESSING, N0 SIGN)
R31=600      (FEED MM/MIN)
R32=3        (NO. OF DRESSING CUTS)
R38=3        (ROT. STONE C.W. ** USED ONLY 3 **)
R39=3500     (STONE RPM)
R801=0       (DELETE DRF OFFSET MEMORIZED IN R801)
L49          (USER SUBROUTINE)
M30
```

Figure 4. Profiling program for calling all subroutines (SPF49 & SPF 201-204).

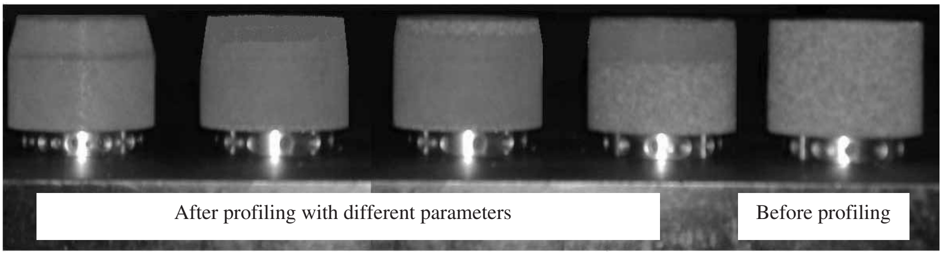

Figure 5. Photograph of actual grinding wheels before and after profiling.

4. Conclusion

The presented algorithm offers an easy way to perform the profiling and dressing operations for grinding wheels. The algorithm reduces the time required for preparing the profiling and dressing of grinding wheel programs, as well as reducing programming error.

Appendix: A

%SPF49

```
( User Subroutine for Profile , Dressing and Zero Offsets )
(**********************************************)
@714
R701 = 551.690 (Distance from Machine Centre to diamond)
R702 = −237.870 (Distance from Machine faceplate to diamond)
(********************** COMMON DATA ************************)
@714
@371 R50 K K @122 R50 K1 K999
@432 K1 K1 K @432 K1 K2 K @432 K2 K2 K
@430 K4 K1 K1 K @430 K4 K2 K1 K0 @434 K1 K @434 K2 K
@300 R90 K2400 @300 R91 K2281
R90 = R90*2 R91 = R91 + 1000 R90 = R90/1000 R91 = R91/1000
L = R28
@714
@320 R99 K1 R27 K ( R99 TOOL TYPE MEMORY )
@111 R99 K1 K700 K2 K700 K3 K700 K4 K700
K5 K800 K6 K800 K7 K800 K8 K800
@100 K995
(*********** GRINDING WHEEL PROFILE CALCULATION - TYPE 1-4 **********)
N700
R45 = R17*R22/2 @637 R46 R45 R22
@630 R50 R46 @631 R51 R46 @632 R52 R46
R53 = R23*R51 R54 = R23*R50 R55 = R23−R53 R69 = −1
R56 = R22 R57 = R56*R52 R58 = R57−R55 R59 = R20/2
R60 = R58/R52 R61 = R56-R60 R62 = R21−R60−R54 + 5
R63 = R69*R58 R64 = R69*R55 R65 = R60 R66 = R54 R67 = R62
R68 = R57/R30 @622 R68 @620 R68
R92 = R25*2 R120 = R20−R92 R92 = R120
R93 = R57*2 R121 = R20−R93 R93 = R121
@122 R21 R22 K44
@100 K45
```

```
@714
N44 R150 = 0
@100 K46
N45 R150 = R22
N46 @123 R93 R92 K993 @123 R92 R26 K994
(********************************************************)
@100 K200
N42 R150 = R22
N43 @123 R93 R92 K993 @123 R92 R26 K994
(********************************************************)
N200
@714
@111 R29 K K1 K1 K35 K2 K30 K12 K30 K3 K40 K4 K20
@100 K992
(**************** PROFILING and TOOL OFFSET ****************)
N1 [INIT MPF, 300, 2]
[START 2]
@714
R94 = 0 R95 = 0 R98 = 0
G G40 G90 D
@706 @440 K2 R91
@706 @440 K1 R90
M2 = R38 S2 = R39
M ( JOG, X axis, touch diamond with stone )
( AUTOMATIC, cycle START )
@714
@361 R70 K1 R70 = R70/2
M ( J0G, Z axis, touch diamond with the face of the stone )
( AUTOMATIC, cycle START )
@714
@361 R71 K2
@111 R99 K1 K701 K2 K702 K3 K703 K4 K704
K5 K801 K6 K802 K7 K803 K8 K804
@100 K995
N701 R750 = R70 R751 = R71 ( G57 FOR TYPE 1 )
@100 K9
N702 R752 = R70 R753 = R71 ( G57 FOR TYPE 2 )
@100 K9
N703 R754 = R70 R755 = R71 ( G57 FOR TYPE 3 )
@100 K9
N704 R756 = R70 R757 = R71 ( G57 FOR TYPE 4 )
@100 K9
(************ PROFILING and TOOL OFFSET - TYPE 1-4 *********)
N9 @430 K4 K1 K R70 @430 K4 K2 K R71
G G57 G90 @440 K1 K-10 @440 K2 K-5 D
N10 @161 R68 K K1000
G1 G91 G94 @440 K1 R30 F = R31 M2 = 18
@440 K1 K5
@440 K1 R94
@440 K2 K5
@440 K1 R63 @440 K2 R65
G3 @440 K1 R64 @440 K2 R66 I = R53 K = R66
G1 @440 K2 R67
```

```
@714
@361 R96 K1
@440 K2 K3
@440 K1 K-5
G G90 @440 K2 K-5
@714
R94=R63+ R64 R94=R94*R69
@714
@621 R68
R95=R95+ R30+ R30 ( CALCULATION STONE CUTS IN DIAMETER )
@100 K-10
N1000 @111 R99 K1 K1005 K2 K1006 K3 K1007 K4 K1008
@100 K995
N1005 R771=R95 ( R771 = MEMORY CUTS IN DIAMETER F0R TYPE 1 )
@100 K1100
N1006 R772=R95 ( R772 = MEMORY CUTS IN DIAMETER FOR TYPE 2 )
@100 K1100
N1007 R773=R95 ( R773 = MEMORY CUTS IN DIAMETER FOR TYPE 3 )
@100 K1100
N1008 R774=R95 ( R774 = MEMORY CUTS IN DIAMETER FOR TYPE 4 )
@100 K1100
N1100
N11
        ( R96= X AXIS POSITION )
R96=R96/2 ( X/2 AXIS POSITION )
R72=R96-R701 ( X OFFSET = POSITION - DIAMOND POSITION )
R73=R71-R702 ( Z OFFSET = POSITION - DIAMOND POSITION )
@420 K1 R27 K2 R72 @420 K1 R27 K3 R73
( LOAD TOOL OFFSET R27 * L1 FROM R72 * AND * L2 FROM R73 * )
@420 K1 R27 K8 K
( LOAD TOOL OFFSET R27 * INPUT "0" L1 BASE * )
@714
[INIT MPF, 301, 2]
@714
[START 2]
@714
G0 G53 G90 @440 K2 K-1690 D0
M2=5
@100 K999
(************************ DRESSING ************************)
N20 M00 ( DRESSING SECTION )
[INIT MPF, 200, 2]
@111 R99 K1 K21 K2 K21 K3 K21 K4 K21
K5 K22 K6 K22 K7 K22 K8 K22
@100 K995
(******************** DRESSING TYPE 1-4 *******************)
N21 @320 R74 K1 R27 K8 @125 R74 R25 K991
R75=R32*R30 R76=R75+R74 @126 R76 R25 K991
R955=R32
M2=R38 S2=R39
M5
G04 F4
@714
```

```
[START 2]
@111 R99 K1 K51 K2 K52 K3 K53 K4 K54
@100 K995
N51 R95=R771 R94=0 R600=R771-10 R98=0
@430 K4 K1 K R750 @430 K4 K2 K R751
@100 K55
N52 R95=R772 R94=0 R600=R772-10 R98=0
@430 K4 K1 K R752 @430 K4 K2 K R753
@100 K55
N53 R95=R773 R94=0 R600=R773-10 R98=0
@430 K4 K1 K R754 @430 K4 K2 K R755
@100 K55
N54 R95=R774 R94=0 R600=R774-10 R98=0
@430 K4 K1 K R756 @430 K4 K2 K R757
@100 K55
N55
[WAIT M 1,2]
G G53 Z1=-1690 D
G G57 G90 @440 K1 R600 D
@440 K2 K-5
N25 @161 R955 K K2000
G1 G91 G94 @440 K1 R30 F=R31 M2=18
@440 K1 K5
@440 K1 R94
@440 K2 K5
@440 K1 R63 @440 K2 R65
G3 @440 K1 R64 @440 K2 R66 I=R53 K=R66
G1 @440 K2 R67
@440 K1 K-5
G G90 @440 K2 K-5
@714
R94=R63+R64 R94=R94*R69
@714
@621 R955
R95=R95+R30+R30
R98=R98+R30
@100 K-25
@714
(*********** DRESSING END AND LOAD TOOL MEMORIES ************)
N2000
@320 R601 K1 R27 K8 R601=R601+R98
@420 K1 R27 K8 R601 R98=0
( LOAD NEW WEAR - TOOL OFFSET R27 * L1 BASE * )
@111 R99 K1 K56 K2 K57 K3 K58 K4 K59
@100 K995
N56 R771=R95 (R771 = MEMORY CUTS IN DIAMETER FOR TYPE 1)
@100 K26
N57 R772=R95 (R772 = MEMORY CUTS IN DIAMETER FOR TYPE 2)
@100 K26
N58 R773=R95 (R773 = MEMORY CUTS IN DIAMETER FOR TYPE 3)
@100 K26
N59 R774=R95 (R774 = MEMORY CUTS IN DIAMETER FOR TYPE 4)
@100 K26
```

```
N26
[WAIT M 3,2]
@714
[WAIT M 4,2]
@714
G G54 G90 @440 K2 R34 D=R27
@440 K1 R33
@100 K999
(********************** ZERO OFFSET Z **********************)
N30 G G53 G90 @440 K2 K−1690 D
G53 @440 K1 K915
(M2=R38 S2=R39)
(M=R40 S=R41)
M2=5
M5
@714
G54 @440 K2 R34 D=R27
@440 K1 R33
M (JOG, stone touching on Z reference plane BY BLOCK 50.8)
(AUTOMATIC, Cycle START)
@714
@361 R80 K2 (READ Z AXIS POSITION)
@320 R81 K1 R27 K3
R97=R80−R81−R36
@430 K3 K2 K R97 @430 K3 K2 K1 K
@440 K2 R34
@122 R29 K3 K35
M2=5
@122 R29 K12 K35
@100 K999
(********************* ZERO OFFSET X ***********************)
N35 @430 K3 K1 K K @430 K3 K1 K1 K @434 K1 K
(LOAD "0" G56 AND RESET DRF ON X AXIS)
G @706 G90 @440 K2 K-1690 D (X AXIS POSITION WITH G53)
G53 @440 K1 K915
M2=R38 S2=R39
M=R40 S=R41
@714
R82=R35+10 (PRESET DIAMETER+10)
R83=R35/2 (RADIUS OF PRESET DIAMETER)
(M (HAVE MADE G56 ON Z1 AXIS))
@714
G56 @440 K2 R34 D=R27
@440 K1 R33 (START X AXIS FOR TOUCHING)
@440 K2 R37 (START Z AXIS FOR TOUCHING)
(M1=7)
G04 F6 (STONE RPM REACHED)
M51 (" BOANO " SELECTION GROUP 0)
G04 F1
@714
M20 (" BOANO " ENABLE)
G04 F1
```

```
M0 (BE CARREFULL – TOUCHING THE PIECE)
G1 G94 @440 K1 R82 F5 (MOVING X AXIS TO TOUCH)
@714
(M (TOUCH ON X)
@714
@361 R84 K1 R84=R84/2 (READ X AXIS POSITION/2)
G @440 K1 R33 (RAPID TURN OFF X AXIS)
G @440 K2 R34 M1=9 (RAPID TURN OFF Z AXIS)
@320 R85 K1 R27 K2 @320 R86 K1 R27 K8
(READ L1 AND L8 * TOOL OFFSET R27)
R87=R84–R83–R85–R86 (R87= X POSITION-PRESET RADIUS-L1-L8)
@714
@430 K3 K1 K R87 (LOAD G56 ON X AXIS)
@430 K3 K1 K1 K (LOAD "0" G56 FINE)
@100 K999
(************************************************************)
N40 @100 K-30
(************************************************************)
(ALARMS)
(************************************************************)
N991
G4 F1 (WEAR STONE OUT ** RESET **)
@100 K-991
N992
G4 F1 (INCORRECT R29 ** RESET **)
@100 K-992
N993
G4 F1 (PROFILE UNDER WEAR STONE ** RESET **)
@100 K-993
N994
G4 F1 (WEAR UNDER MINIMUM STONE DIAMETER ** RESET **)
@100 K-994
N995
G4 F1 (TOOL TYPE INCORRECT ** RESET **)
@100 K-995
(******************** SUBPROGRAM END **********************)
N999 M17
```

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