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Enhanced CNC lathe capability by addition of a grinding spindle

A. T. ABBAS†

CNC grinding machines are widely used to obtain a good surface finish and tight tolerances. However, these machines are expensive, therefore manufacturers are considering adding a grinding spindle, interchangeable with a boring bar, to a turning lathe. To facilitate this, complex software is required because the programmer must control the whole surface of the grinding wheel not just the tool or cutter tip, as in turning or milling. This paper presents a general algorithm to simplify the grinding programme. The programmer will use this algorithm to create a subroutine suitable for the machine. The subroutine may then be used for all grinding operations. The programmer will need only to describe the contour of each workpiece, as for a CNC lathe program, in a separate small program. The algorithm has been applied to a hollow spindle lathe equipped with Sinumeric 840 C numerical control, and several gun barrels were turned and ground using the proposed approach. Satisfactory results were obtained.

1. Introduction

Grinding operations are necessary for many engineering applications that require components to have tight tolerances, particularly in parts that will be coated by hard chrome plating. CNC grinding is widely applied to parts having increasingly complex geometry. However, the cost of machining on CNC grinding machines is very high, particularly when used for low or medium production volumes (Luggen 1983, Groover and Zimmers 1984). Companies are therefore beginning to consider adding a grinding spindle onto a CNC turning lathe.

There are several benefits from adding the grinding spindle, which is interchangeable with the turning boring bar, to the hollow spindle lathe. The grinding spindle eliminates the need for an additional grinding machine, saving money and factory floor space. The required machine spare parts are reduced, as well as operator training, and the operator needs only to be trained on the additional grinding operation rather than on a complete new machine and control system. The transfer of parts from the lathe to the grinding machine, and additional set-up time, is eliminated. The part remains clamped to the spindle at the end of the turning operation, ensuring concentricity of turned and ground features. Maintenance personnel only require additional training on repair of the grinding option and not a complete new machine and control (Siemens 1999a, b).

To avoid the effect of grinding dust and grit on the lathe guideways and bearings, three items should be added to the lathe system; telescopic covers to protect the guideways, a filtration system for cutting fluid and an extraction system for removal of dust during dressing of grinding wheels.

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† Ministry of Military Production-MF100, 9 Mahmoud Talaat St.-Nasr City-Cairo-PO Box 5888, Heliopolis West, Egypt. e-mail: atabbas@soficom.com.eg

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However, the main problem associated with adding a grinding spindle to a CNC lathe is that the control software for the 'add on spindle' is very long and complicated. A different type of software is needed; such as software for profiling a new grinding wheel or dressing an old grinding wheel, as well as the software required for programming grinding of the workpiece.

In this work, a general algorithm has been created that can be used to generate a grinding subroutine suitable for use on a hollow spindle NC lathe. The algorithm is demonstrated for programming the grinding of the combustion chamber of a gun barrel on a CNC lathe equipped with Sinumeric 840C numerical control.

2. General algorithm

Figure 1 is the general algorithm suitable for creating a subroutine for any modern type of CNC control.

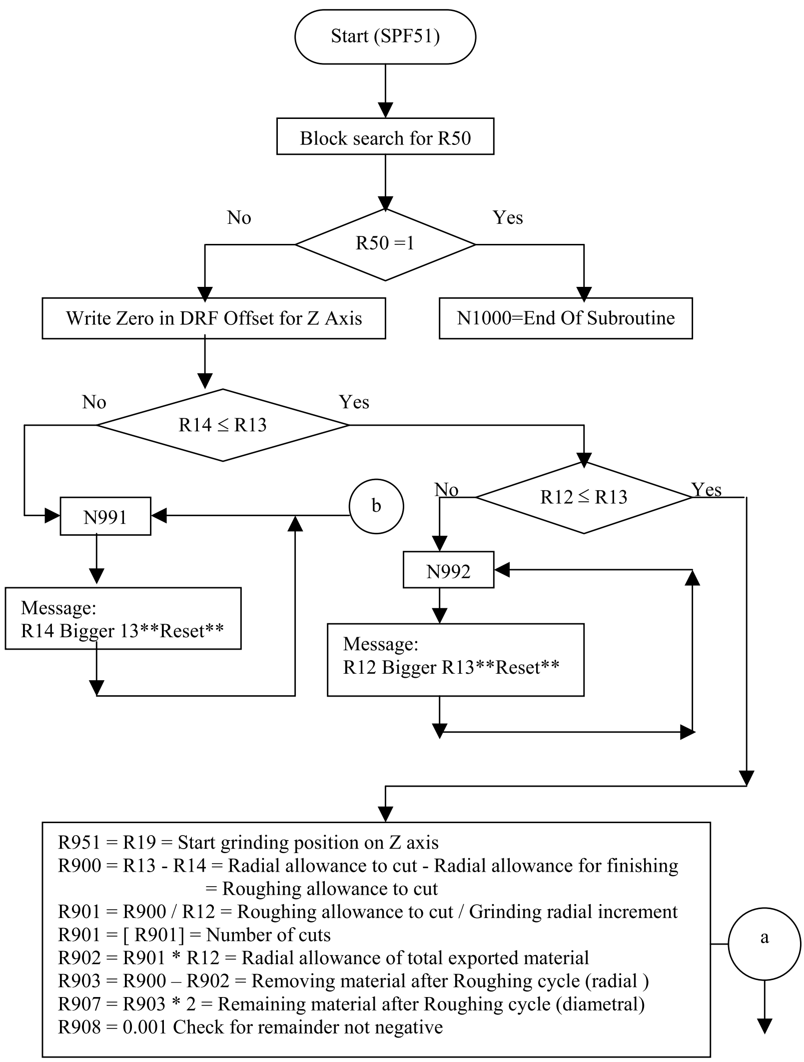

Figure 1. The general algorithm.

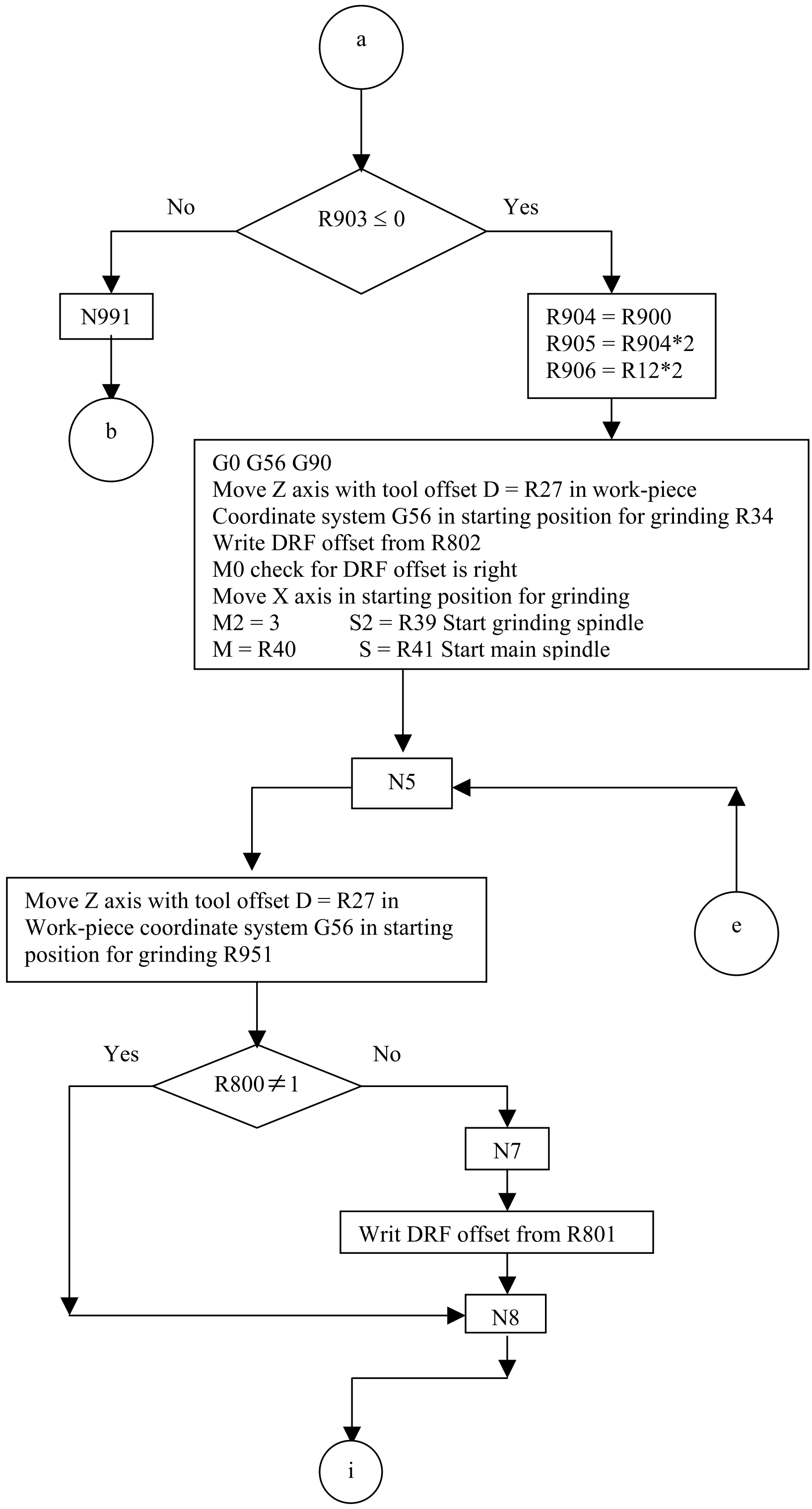

Figure 1. *Continued.*

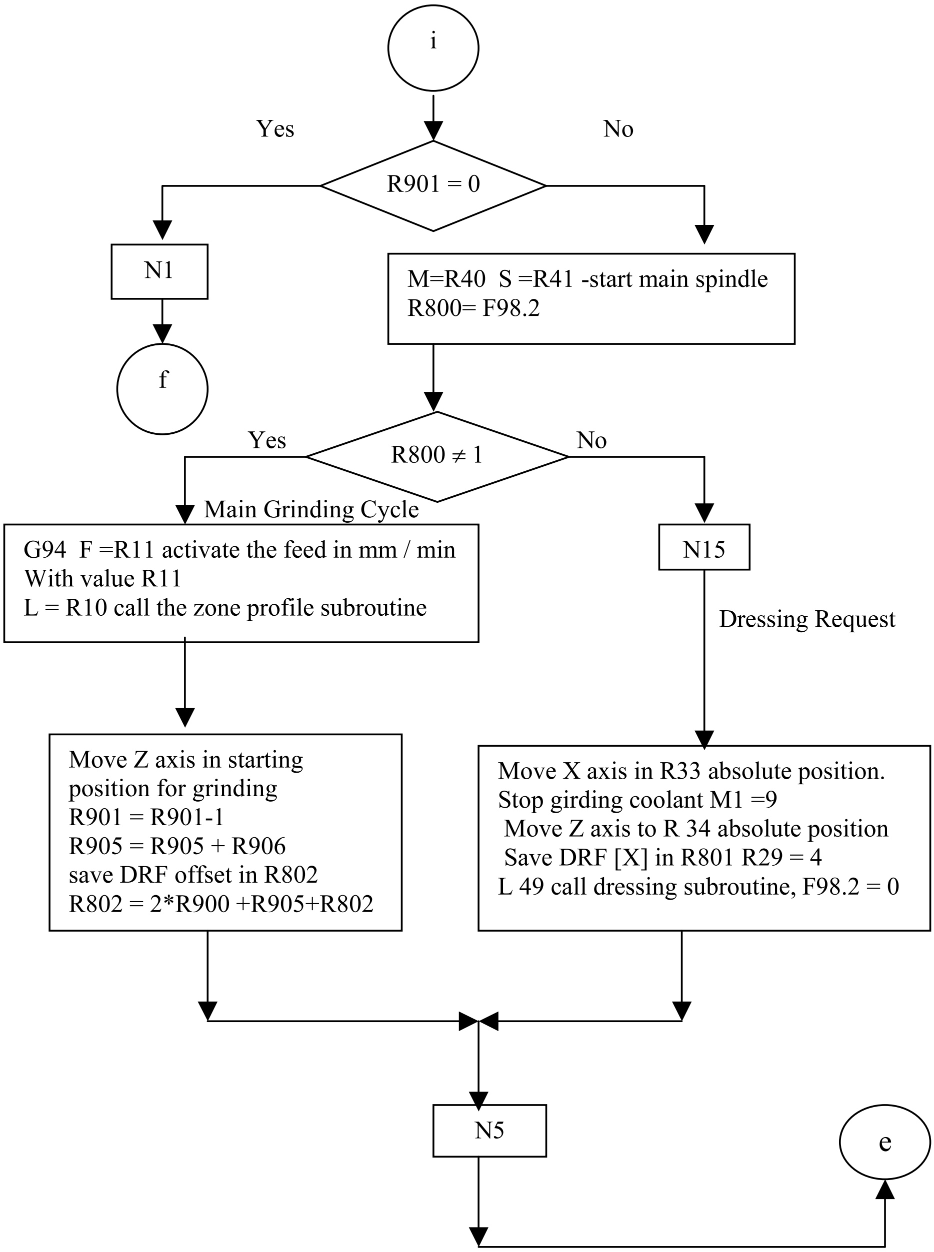

Figure 1. *Continued.*

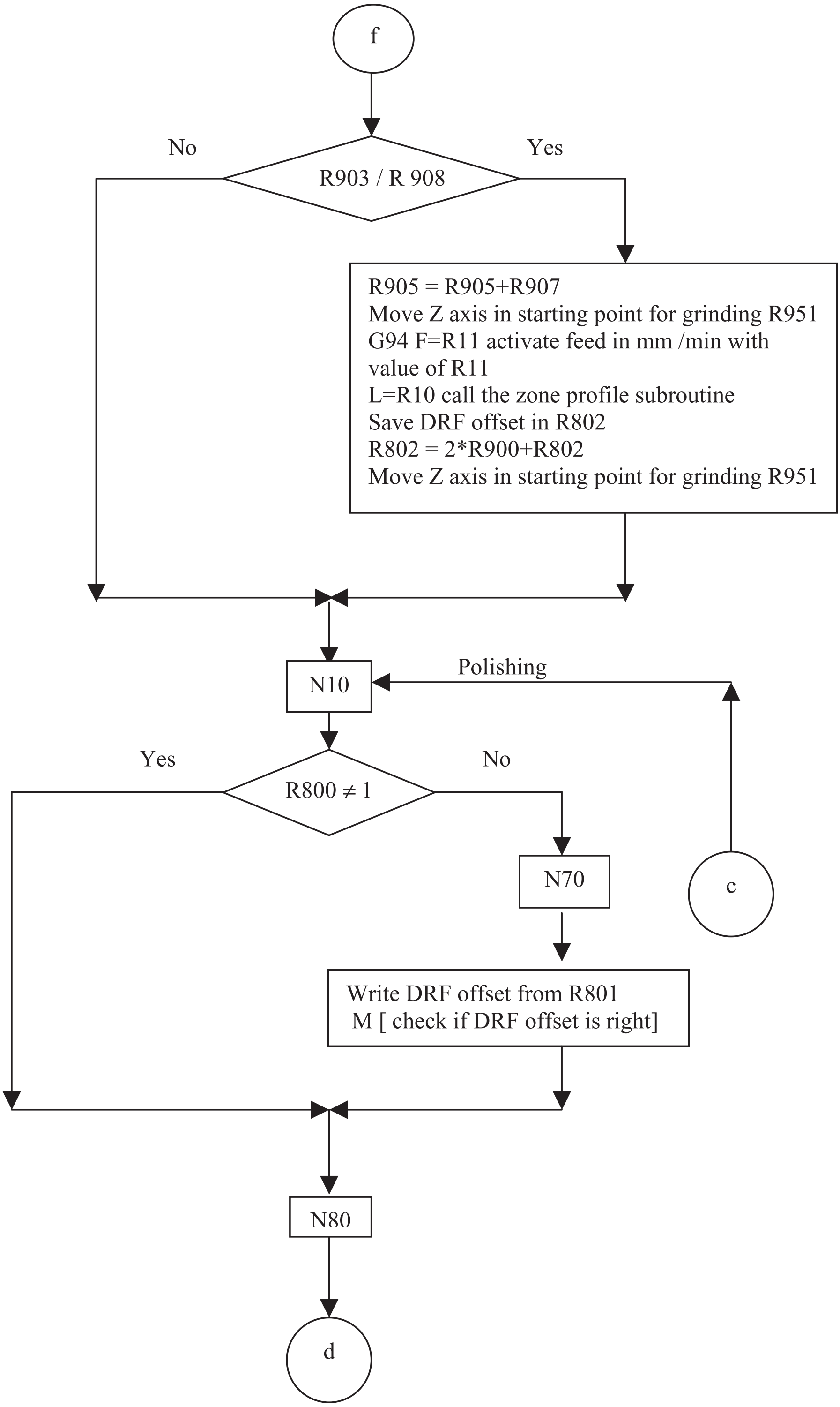

Figure 1. *Continued.*

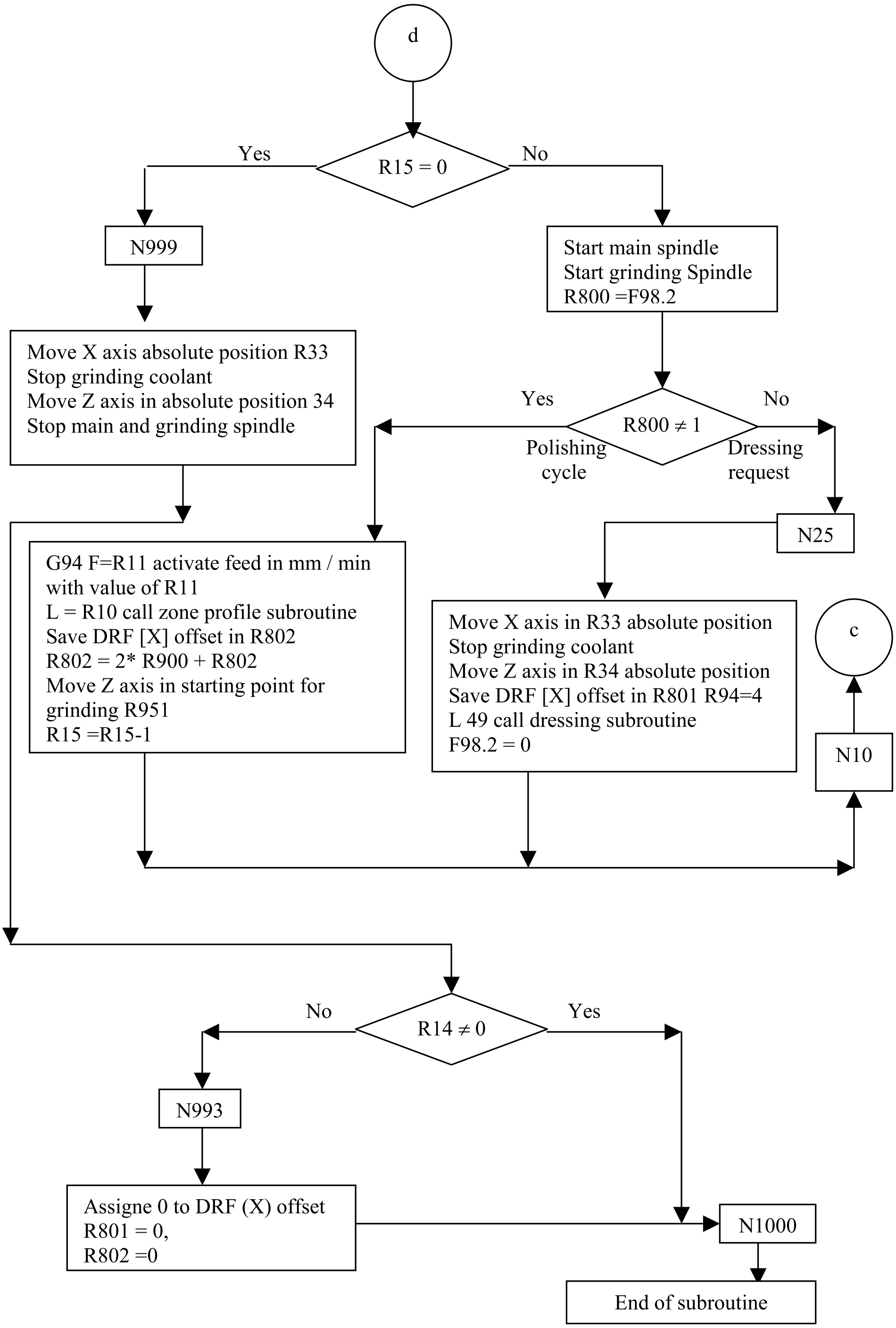

Figure 1. *Continued.*

3. Application example

The algorithm in figure 1 has been used to create a subroutine (SPF51) suitable for a CNC lathe with Sinumeric (840-C) control, as shown in Appendix A. After storing the subroutine in the CNC unit, it is used in all grinding operations on the turning machine.

For example to grind the combustion chamber of a gun barrel the barrel chamber is divided into three or four different zones depending on the shape and length of the chamber. The programmer writes small subroutines (SPF11) to describe the profile of each of the grinding zones, such as shown in figure 2.

The CNC unit will also need a program such as (MPF61), shown in Appendix B, to call the different subroutines that are used in the grinding operations, and which contain all required grinding parameters.

The algorithm was used to create the program for grinding the combustion chamber of gun barrels on the same CNC lathe that was used for the turning operation, but also using an add-on grinding spindle. The set-up is shown in figure 3.

```
% SPF11
(Grinding profile zone 1)
N010 G1 G90 X1=142.414+R905 Z1=-10
N020 X1=127.99+R905 Z1=496 M1=7
N030 X1=120.25+R905 Z1=650 B100
N040 X1=116.68+R905 Z1=783
N050 M1=9
N060 M17
```

Figure 2. Subroutine for grinding zone.

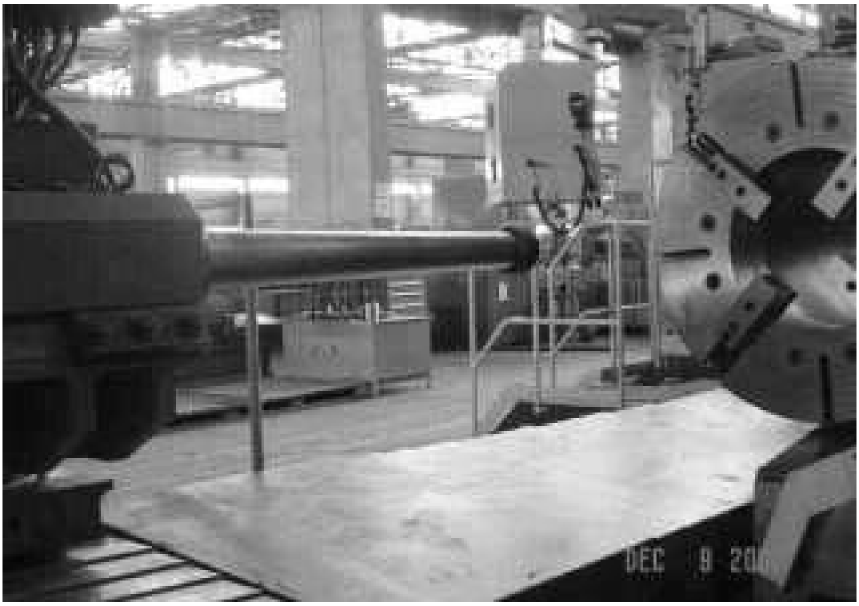

Figure 3. Set-up for add on grinding spindle.

The time for the grinding operations on the CNC lathe was about the same (four hours) as on a CNC grinding machine. However, the average set-up time for grinding on the CNC lathe is only five minutes compared with two hours for a CNC grinding machine. On average, the saving on set-up time was 96%, and the total cycle time was reduced by 30%. An acceptable surface finish was achieved, and dimensional accuracy within ± 0.015 mm was obtained.

4. Conclusions

The new algorithm offers an easy way to program and perform grinding operations on a CNC lathe. The algorithm reduces the time required for preparing the part program and reduces programming error. Implementation of the algorithm on a CNC lathe and application to a real turned and ground example component has demonstrated the effectiveness of the algorithm and the time cost reductions that can be achieved.

Appendix A

```
SPF51
(User defined subroutine for grinding profile)
 @714
 @371 R50 K K @122 R50 K1 K1000
 @434 K2 K
 @126 R14 R13 K991 @126 R12 R13 K992
 R951=R19 R900=R13-R14 R901=R900/R12 @622 R901 R902=R901*R12
 R903=R900-R902 R907=R903*2 R908=0.001 @124 R903 K K991
 R904=-R900 R905=R904*2 R906=R12*2
N3 G G56 G90 @440 K2 R951 D=R27
 @714
 @434 K1 R801
 M00 (Check if DRF offset is right)
 @440 K1 R33
 M2=3 S2=R39
 M=R40 S=R41
N5 G00 G56 G90 @440 K2 R951 D=R27
 @714
 @122 R800 K1 K7
 @100 K8
N7 @434 K1 R801
 M00 (Check if DRF offset is right)
N8 @161 R901 K K1
 M=R40 S=R41
 @714
 @382 R800 K1 K98 K2 @122 R800 K1 K15 (READ F98.2 IF =1)
 G94 F=R11
 L=R10
 G00 G56 G90 @440 K2 R951 D=R27
 @714
 @621 R901
 R905=R905+R906
 @714
 @100 K-5
 @714
```

```
N1 @124 R903 R908 K10
 @714
 R905=R905+R907
 G00 G56 G90 @440 K2 R951 D=R27
 G94 F=R11
 L=R10
N10 G G56 G90 @440 K2 R951 D=R27
 @122 R800 K1 K70
 @100 K80
N70 @434 K1 R801
 M00 (Check if DRF offset is right)
N80 @161 R15 K K999
 M=R40 S=R41
 M2=3 S2=R39
 @714
 @382 R800 K1 K98 K2 @122 R800 K1 K25
 G94 F=R11
 L=R10
 G G56 G90 @440 K2 R951 D=R27
 @714
 @621 R15
 @100 K-10
 @714
N15 G G90 G56 @440 K1 R33 D=R27 M1=9
 @440 K2 R34
 @714
 @333 R801 K1
 @714
 R29=4 L49 (Call Dressing Subroutine)
 @714
 @482 K1 K98 K2 K (PUT F98.2=0 After Dressing)
 @714
 @100 K-5
N25 G G90 G56 @440 K1 R33 D=R27 M1=9
 @440 K2 R34
 @714
 @333 R801 K1
 @714
 R29=4 L49 (Call Dressing Subroutine)
 @714
 @482 K1 K98 K2 K (PUT F98.2=0 After Dressing)
 @714
 @100 K-10
N991
 G4 F1 (R14 Bigger R13 **Reset**)
 @100 K-991
N992
 G4 F1 (R12 Bigger R13 **Reset**)
 @100 K-992
N999 G G90 G56 @440 K1 R33 D=R27 M1=9
 @440 K2 R34
 M2=5
 M5
```

```
 G53 X1=1600 D
 @122 R14 K K993
 @714
 @333 R801 K1
 @714
 R801=R801+R900+R900
 @100 K1000
N993 @434 K1 K
 R801=0
N1000 M17
```

Appendix B

```
 %MPF61
 (PROGRAMME Zero Offset G56 Z1 and X1 + GRINDING)
 (ZERO OFFSET IN Z1 AND X1 AXES IS ALREADY DONE AND)
 (YOU DON'T WANT TO DO IT AGAIN?)
 (IF*YES*BLOCK SEARCH TO N1, IF*NO*CONTINUE WITH CYCLE START)
(*************** GRINDING PARAMETERS *****************)
R10=11 (No. subroutine of Workpiece profile)
R11=500 (Grinding feed mm/min)
R12=.002 (Grinding radial increment, NO sign)
R13=0.034 (Radial allowance to cut, 3 FIGURES AFTER COMMA ONLY)
R14=0.020 (Reached position, 0 is final = Total allowance)
R15=1 (No. of free cuts, polishing)
R19=-50 (Start GRINDING position on Z axis)
(************** ZERO OFFSET PARAMETERS ***************)
R27=201 (Tool Offset grinding wheel)
R28=201 (Subroutine No. of stone DATA)
R29=12 (R29= 1 - Zero offset X1)
(R29= 2 - ZERO OFFSET Z1)
(R29=12 - ZERO OFFSET FIRST Z1, SECOND X1)
R30=.005 (Radial increment to dressing, NO sign)
R31=300 (Feed mm/min to dressing)
R32=3 (No. of dressing cuts)
R33=115.73 (X axis position G56 turn off from collision)
 (TO COME IN MACHINE CENTER,R33 MUST BE THE)
 (ACTUAL MAXIMUM DIAMETER OF STONE)
R34=-150 (Z axis position G56 turn off from collision)
R35=128.15 (X axis diameter REFERENCE for zero offset)
R36=-50.8 (Z axis REFERENCE for zero offset)
R37=550 (Z axis position for zero offset X axis)
(*************** SPINDLE PARAMETERS *****************)
R38=3 (Stone rotation only CW=3)
R39=3500 (Stone Rpm)
R40=4 (Spindle rotation CW or CCW, 3 or 4)
R41=40 (Spindle Rpm )
(****************** ZER0 OFFSET ********************)
L49
(**************************************************)
M00 ( ARE YOU ALREADY DONE ZERO OFFSET IN Z1 AND X1 AXES ?)
(IF**YES**CONTINUE WITH CYCLE START,IF**NO**RESET AND DO THIS)
M00 ( YOU WANT TO CONTINUE WITH GRINDING ?)
(IF**YES**CONTINUE WITH CYCLE START,IF**NO**RESET)
```

```
(******************** GRINDING ***********************)
N1 L51
M30
```

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