DIRECT MILLING ON CNC CAROUSEL

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The article discusses an application of new possibilities for the older type of machine. This machine is a heavy vertical lathe in the single column design (series carousel SKJ) which after modernization has a new CNC control system. It has a generally wide range of standardized machining cycles, which are determined not only for carousels. When upgrading the system usually not all software on the machine is operational. That would be useless and expensive. Limited possibilities of the original carousel are then enhanced by the software. In particular, it is the machining of non-rotating surfaces on rotary components. Longer production cycle shorten time because there is no need to move the direct machining to another machine. The operation of these heavy machines are energy-intensive, so the use of advances positively influence the economy of production.

KEYWORDS

carousel, adjustable rotation axis, milling, CNC system, Sinumerik, cartesian coordinates

1 INTRODUCTION

The model series of proven carousel lathes of CKD Blansko Strojirny and TOS HULIN can be equipped with a controlled rotary C - axis, which rotates around a vertical Z - axis with a positioning position of 0.001°. These machines have high energy consumption and therefore their maximum use is required [Osicka 2017], [Sedlak 2015]. CNC control systems for these machines are an integral part of the new machine or there are retrofitted during the reconstruction of the older machine. Usually CNC systems are from the Siemens Sinumerik series, typically the Sinumerik 840D. The 840D system is universally applicable CNC control system for different types of machines. The system is already equipped with software beyond the possibilities of the carousel. If the machine has a positionable rotary axis C, then it can to machine in a plane perpendicular to the Z - axis (plane G17), e.g. milling. This makes it possible to use the features of the milling machine on a carousel lathe. If company software is available then we can use this when programming the machining process. The second option is to insert special blocks into the normal main NC program.

2 CONSTRUCTION OF MACHINED COMPONENTS

Dimensional rotation components may contain non-rotational surfaces. These areas have to be machined by means of linear movements in different directions (bends, corners, pockets). Here, high precision is not necessary. When using a standard carousel this means a problem, the simple rotation of the workpiece is not suzfficient in this case. An example of the part is shown in (Fig. 1).

3 TECHNOLOGICAL PROCESS

The technological process is based on the carousel machining principle [Kocman 2005], [Team of authors 1997], [Piska 2009]. For machining rotary shapes, the user normally builds the main NC program. The linear milling blocks are then added in the form of a subroutine. When a component contains multiple irregularly spaced areas, it is necessary to specify the coordinate system offset (G54, G55, G56, G57, etc.) for each subroutine. The displacement is calculated in accordance with the drawing documentation or by physical adjustment directly on the machine before the machining starts or when the automatic operation of the NC program is interrupted by the stop function M0 / M1. The operator carries out only the machine control system and the milling machine does not have to be moved and clamped to another machine what would be a milling machine [Shaw 2005].

Figure 1. Example of rotation component with non-rotating surfaces [TOS HULIN 2017]

4 CAROUSEL WITH ADJUSTABLE ROTATION AXIS

On a carousel with a rotary axis C, the milling can also be programmed in a straight-through trajectory. The carousel must be equipped with an adapter for rotary tools (Fig. 3). This machine equipment significantly increases the possibilities of its use [Humar 2008]. The NC program was debugged on the SKJ32-63 CNC machine (Fig. 2) with the Sinumerik840D control system (max. Circulating diameter 4000 mm, work piece max. 50000 kg, power 195 kW) [Siemens AG 2000].

Figure 2. SKJ32-63 CNC, carousel with adjustable rotation axis C [CKD BLANSKO 2017]

5 NC PROGRAM FOR MILLING THE CAROUSEL

In the case of an older type of machine, where the company user can not afford an innovation, the aforementioned software solution comes to the use [Imai 2004], [Stulpa 2007]. This program is complemented by a subroutine that contains blocks with mathematical algorithms. These algorithms calculate the linear tool paths in the direction of the rotation radius with the possibility of angular deflection (Fig. 1 and 3). A file with an ARC extension is created when the main NC program is backed up. This file contains all related subroutines and machine setup data. An ARC file can be commonly used on computers and performs operations such as archiving, copying, renaming, editing, back-loading to the control system.

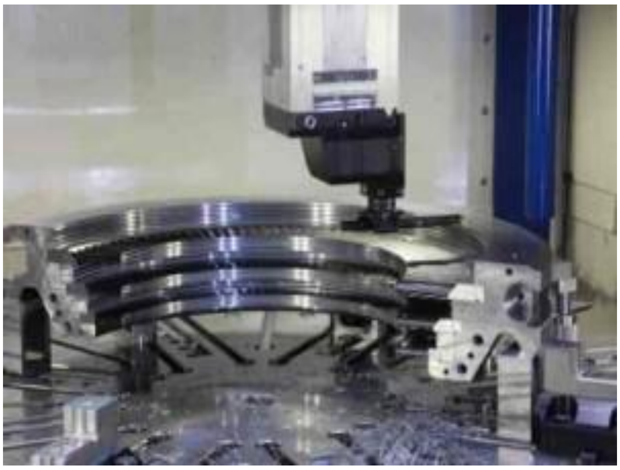

Figure. 3. Possibilities of the linear tool path relative to the radius of rotation [CKD BLANSKO 2017]

5.1 *Mathematical algorithms for tool*

For programming of simple tool path situations, functions with ISO standards (DIN66025) such as G0, G1, G2, G3 are sufficient. For a carousel with a positionable rotary axis, it is possible to use the more demanding forms of linear tool path programming, that is to bind the movement of the C axis and the X axis in the G17 plane by a precisely defined binding [Freibauer 2010]. The theoretical line from the starting point to the target point is replaced by a broken line (Fig. 4). The broken line is defined by mathematical algorithms simultaneously with the use of parametric programming. The fineness or roughness of the line break determines the parameters (Tab. 2 and 3). The situation (Fig. 4) is 5x enlarged compared to the record of the substitution simulation. Two versions of the NC program are processed according to the operability of use:

a) Simpler short version, perpendicular tool path to rotation radius (Fig. 7 and 8),

b) Longer more complex versions, inclined to the radius of rotation (Fig. 9).

Version a) is detailed in the article.

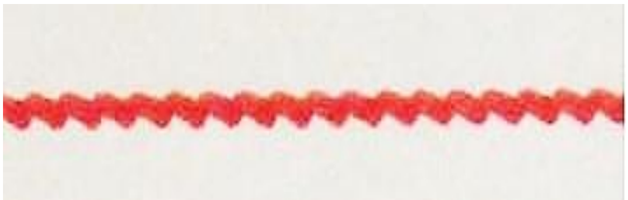

Figure 4. Detail of a linear tool path from a substitution simulation

5.2 *NC program version a)*

The specific form of the NC program blocks is next (tab. 1). Three blocks here are protected, unpublished. The NC program has the authoritative name PERPENDICULAR_LINE_OKF, and it can be used, for example, as a subroutine in other user-built main NC programs.

```
@@MMCARC.0017060324211184611968241‌6\MPF.DIR\
PERPENDICULAR_ LINE_ OKF .MPF /_N_ PERPENDICULAR_
LINE_ OKF _MPF
PERPENDICULAR_ LINE_ OKF.MPF 65775 7 060324 2225
1184611968 5676*/_N_MPF_DIR/
%_N_ PERPENDICULAR_ LINE_ OKF_MPF
;$PATH=/_N_WKS_DIR/_N_ PERPENDICULAR_ LINE_ OKF
_WPD
; MILLING OF THE PERPENDICULAR LINE TO THE AXIS X,
; THE BEGINNING IS ON THE X-AXIS,
; THE DIRECTION IS 90 DEGREES,
; WARNING: THE MACHINED CONTOUR IS BETWEEN
; THE TABLE AXIS AND THE MILLING CUTTER
; ENTERED VALUES (PARAMETERS ARE EDITED MANUALLY)
R10=1001
; THE STARTING POINT OF THE CUTTER AXIS( AXIS X)
;  DIRECTION TO THE RIGHT IN THE POSITION OF THREE
HOURS
; PARAMETER RANGE VOLUME FROM 1000 MM
R11=359
; TOTAL LENGT
; VECTOR FROM THE BEGINNING TO THE ENDPOINT
; PARAMETER RANGE VOLUME TO 360 MM
R12=0.099
; STEP IN THE AXIS  C
; STEP TO 0.1 DEGREE
R13=+1
; SENSE OF MOVEMENT OF THE TOOL TO THE TABLE
; -1 DIRECTION "12 HOURS"
; +1 DIRECTION "6 HOURS"
; R14 UNOCCUPIED
; R15 UNOCCUPIED
R16=2.3 ; ANGLE CORRECTION

; START OF THE PROGRAM
N100 R20=0 ; ASSISTED PARAMETER, DO NOT EDIT
N110 G90 G17 G94 G40 ; ATTENTION ON THE PLANE G17
N120 G54
; N130 M2=4 S2=480 M7
; M2=4 ROTATE RIGHT
N140 G64 ; CONTINUOUS CONTROL MODE
N150 G1 Z100 F2000 ; SECURITY DEPARTURE
N160 X1100 ; X-AXIS APPROXIMATION
N170 C=DC(0) ; C-AXIS APPROXIMATION
N180 Z0
N190 X=R10 F1600
N300 MARKE1:
N310 R20=R20+R12 ; ABSOLUTE ANGLE SIZE
N320 R21=R13*R20 ; DIRECTION AND ROTATION OF C AXIS
N330 R22=..............; X-AXIS INCREMENT
N340 R23=..............; ABSOLUTE LENGTH OF THE X AXIS
N350 R24=..............; "Y" ABSOLUTE LENGTH ROTARY AXIS C
N360 R17=R24*(SIN(R16))
N410 C=R21 F1600
N420 G4 F0.6 ; DWELL TIME IN SECONDS
N430 X=R23+R17 F1600
N440 IF R24>=R11 GOTOF MARKE2
N450 GOTOB MARKE1
N500 MARKE2:
N510 M9
N520 G1 Z100 F2000 ; SECURITY DEPARTURE
N530 X1100 ; THE BEGINNING IS ON THE X-AXIS
N540 C=DC(0)
N550 M5
N560 M2
; INSTRUCTIONS FOR USERS
; THIS PROGRAM IS A BUILD-PURPOSE MILLING LINE SEGMENT
; PERPENDICULAR TO THE AXIS X.
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; THE BEGINNING OF THE LINE IS ALWAYS ON THE X-AXIS.
; RADIUS CORRECTION IS NOT USED.
; THE MACHINED CONTOUR IS BETWEEN THE TABLE AXIS AND
; THE MILLING CUTTER.
; THE RESTART OF THE PROGRAM WILL AGAIN RESTART
; THE LINE WITH THE START ON THE X AXIS.
; THE MOVEMENT AND DELIVERY OF MOVEMENT IS.
; ACCORDING TO THE UPDATE OF THE PARAMETER
; APPLICATIONS.
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Explanatory notes:

a) The NC program is an ARC file backed up directly from the Sinumerik840D control system, the first four lines are truncated and left only for backup information.

b) Blocks embedded with a character; (Semicolon) are text, the control system does not perform them, it mainly serves the machine operator how to handle the NC program.

c) The time delay G4 (block N420) is included due to the inertia of the table with the large workpiece clamped. If inertia does not move the drives too much, G4 can be canceled, machine time is shortened.

d) Blocks N330, N340 and N350 are protected, unpublished. They contain parameters R10, R20, R22, R23, R24.

Table 1. NC program PERPENDICULAR_ LINE_ OKF

5.3 *Parametric options of the NC program*

The versatility of using the PERPENDICULAR_LINE_OKF NC program is determined by the parametric programming capabilities of the Sinumerik 840D control system. An explanation of the parameter function is given in the table (Tab. 2). Parameters R14 and R15 are unoccupied. Limitations of validity of the parameters in the form of recommended intervals and operating instructions are in the next table (Tab. 3). The goniometric functions used to define a broken line of the toolpath are not linear (Fig.5). It is recommended to move at these intervals to avoid increased inaccuracies. To determine values, the programmer uses the data from the drawing documentation. The user determines the tool path geometry, defines the used tool (roughing or finishing cutter) according to the surface quality requirement Ra. The user then sets the values by the usual editing of blocks located in the NC program start. Exceeding the recommended intervals then increases the inaccuracy of the generated toolpath. This situation does not have to worry about rougher flat milling (Fig.6). The cutting conditions are set by default from company catalog databases.

parametr	significance
R10	the starting point of the cutter axis(axis x)
R11	total lengt path of milling cutter
R12	angular step in the C axis
R13	sense of movement of the tool to the table, -1 direction "12 hours" , +1 direction "6 hours"
R16	angle correction in the C axis
R17	calculation parameter
R20	calculation parameter
R21	calculation parameter
R22	calculation parameter
R23	calculation parameter
R24	calculation parameter

Table 2. Parameters used in the NC program

parameter	recommended interval	Unit of measure
R10	min. 1000	mm
R11	max. 360	mm
R12	0,001 – 0,1	°
R13	-1 direction "12 hours" +1 direction "6 hours"	- -
R16	to 3 (higher values have a coarsely broken line)	°

Table 3. Parameters selection instructions (for SKJ32-63CNC)

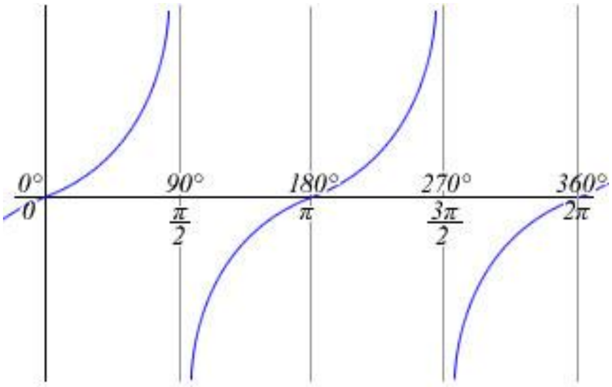

Figure 5. Nonlinearity of goniometric function

5.4 *Sample of machining preparation in the engineering company*

The older machine type did not involve simulation in the control system in this case. The simulation was solved in a substitute way. A paper was placed on the rotary table surface. The tool in the spindle (clamped cutter) has been replaced by a labeling tool. This marker drew a specific path on the paper. These records documented actual movements (Fig. 6 to 9). Machining according to the assembled NC program was started after a replacement simulation for a particular component.

Figure 6. Real tool path, demonstration of the effect of R16 on the fineness of the line break

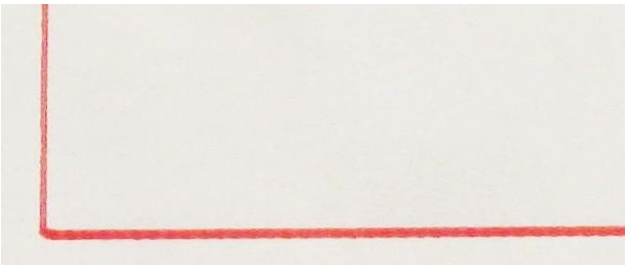

Figure 7. Real tool path, start of linear path

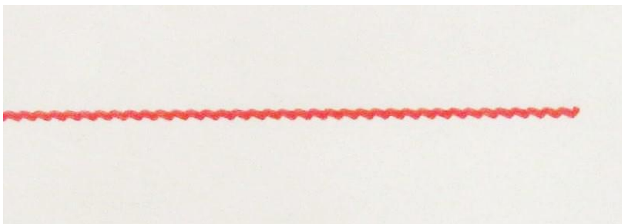

Figure 8. Real tool path, end of linear path

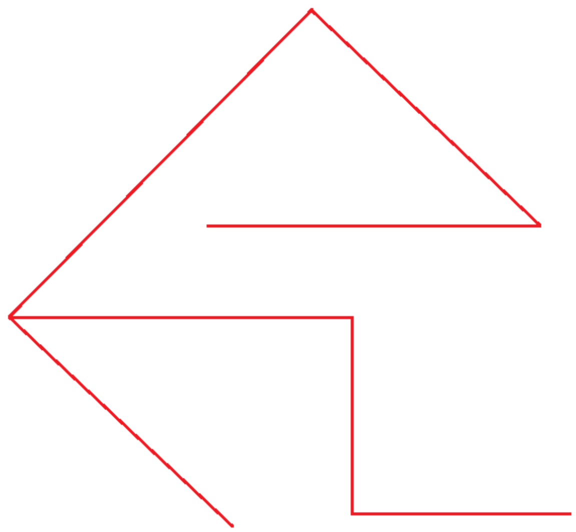

Figure 9. The real tool path, consisting of several adjacent sections, inclined to the radius of the table rotation

6 DISCUSSION

NC program PERPENDICULAR_ LINE_ OKF contains blocks with mathematical algorithms. It is not recommended to perform any interventions in these blocks. These interventions may cause the NC program to fail or work-related crashes. Three blocks are protected and their content is not disclosed. The full version of the NC program is protected by copyright. If necessary, complete versions 1 and 2 are available to the authors. The authors take no responsibility for the consequences resulting from unauthorized modifications of blocks in NC programs.

7 CONCLUSIONS

The article shows the possibility of extending the assortment of machined parts on an older type carousel with a position able rotational axis C. Expansion allows you to cut rectangular or straight surfaces on a rotating table. This option is advantageous when machining large dimensional components such as different cabinets, gearboxes, brackets, lids etc. There is not enough only to standard rotary machining. For machining non-rotating surfaces by milling, the part has to be moved to another machine. This means loss of time and disadvantageous handling of the large part, or the need for an area for storage of finished production [JUROVA 2009], [JUROVA 2011]. These activities are closely related to the ecology, environmental protection and ergonomics of the workplace [TEAM OF AUTHORS 2006], [NORM I 2004], [NORM II 1999].

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