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MT-CNC / MTC200
Transformation Function
V15

Description of Functions

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Purpose of the document This document describes the transformation function and the related requirements.

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Phone +49 (0)9352/40-0 • Tx 689421 • Fax +49 (0)9352/40-4885

Dept. ENC (GL)

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1 Using the Transformation Function

Face machining of turned parts on turning and grinding machines is the chief application of the „Transformation of Cartesian coordinates into polar coordinates“ function.

That function is particularly useful for milling surfaces on turning machines and for grinding camshafts. Furthermore, the function may also be employed in other applications, such as milling machines with rotary tables or with rotating heads (double swivel head).

A transformation from Cartesian coordinates to polar coordinates makes programming significantly easier because the movements that are to be produced are programmed in a fictitious Cartesian coordinate system, whilst the machine perform the necessary movements in the existing real polar coordinate system.

2 Method of Operation of the Transformation Function

2.1 Abbreviations

- R1 real linear axis (first real axis)
- R2 real rotary axis (second real axis)
- F1 first fictitious linear axis
- F2 second fictitious linear axis

Note: These abbreviations are merely used for explanation.

2.2 Transformation

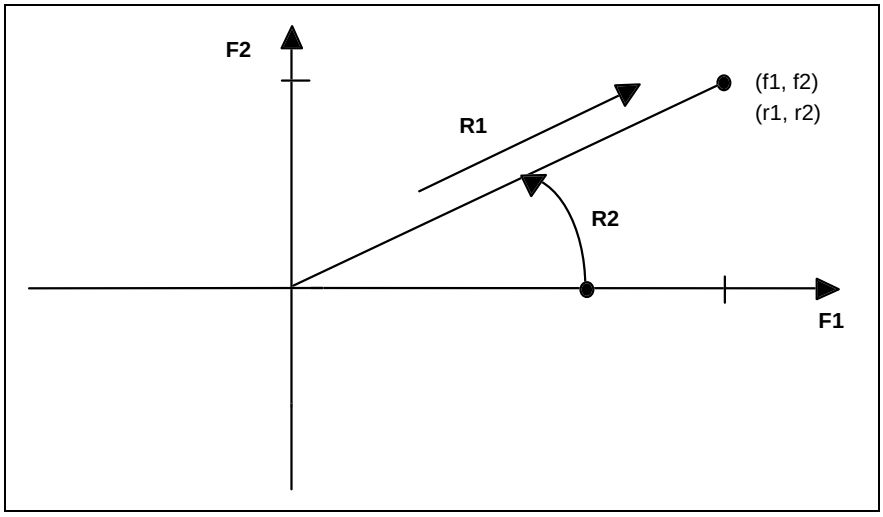

Fig. 2-1: Fictitious Cartesian coordinates (F1, F2) and real coordinates (R1, R2)

Programming is performed in the fictitious Cartesian coordinate system (F1, F2), whilst the machine movements are performed in the real machine coordinate system (polar coordinates: R1, R2).

R1 is always positive; R2 varies between 0 and 360 degrees.

If the coordinate origin is crossed during a transformation, the controller commands R2 to rotate by 180 degrees at F1=F2=R1=0.

Note: The R1 axis must be moved to the positive section (R1>0) before transformation is switched on.

2.3 Automatic Adaptation of the Path Velocity

As it is done for milling, the path velocity for the transformation function must be specified via the F value as a relative velocity between tool and workpiece.

The MT-CNC continuously adjusts the path velocity during interpolation to the requirements of the actual path in order to move along the path at the highest velocity possible (taking the programmed path velocity into account).

The automatic adaptation of the path velocity provides the following benefits for the user:

- No restrictions of the working area
  (movements across the coordinate origin are permitted).
- No additional programming and no additional knowledge required (the path velocity must be specified as in the milling process; independently of the actual distance from the coordinate origin).
- No unnecessary time losses
  (due to the automatic adaptation of the path velocity, the controller always moves the related axes at the maximum velocity possible, taking the programmed path velocity into account).
- No sporadic machine standstill
  (the maximum permissible axis velocity and acceleration values will not be exceeded if machining employs tools of a diameter that is different than the originally assumed value).

3 Fictitious Axes

3.1 Basics

The fictitious axes F1 and F2 are not directly allocated to drives. Instead, they are allocated indirectly via a formula.

The fictitious axes F1 and F2 are required in the transformation function n order to be able to program the movements of the real axes R1 and R2 in a physically non-existent Cartesian coordinate system.

3.2 Axis Meanings of the Real and Fictitious Axes

The MT-CNC supports the transformation function for the XY plane (G17). Consequently, the real axes R1 and R2, that participate in the transformation, must have the axis meanings X and C:

General name	Axis meaning	Axis type
R1	X	digital linear axis
R2	C	digital main spindle with rotary axis capability, or digital rotary axis

During transformation, the fictitious linear axes F1 and F2, that are allocated to the transformation function, behave like linear main axes.

General name	Axis meaning	Axis type
F1	X	fictitious linear axis
F2	Y	fictitious linear axis

In order to be able to

- move along a circle,
- to be able to correctly take the tool compensation values into account, and
- to perform a realistic calculation of the resulting axis velocities on the basis of the programmed path velocities,

the MT-CNC assigns the fictitious axis F1 the axis meaning X and the fictitious axis F2 the axis meaning Y.

The last item is particularly significant for movements in space that are performed during transformation. Without that feature, the velocity components of the axes F1 and F2 could not be taken into account in the velocity computation.

Example

A lathe with integrated Y and C axis and driven tools possesses the following real and fictitious axes:

General name	Programmable axis designation with inactive transformation	Axis designation with inactive transformation	Programmable axis designation with active transformation	Axis designation with active transformation	Axis type
R1	X (axis des. 1) Y (axis des. 2) Z	X Y Z	- Y (axis des. 2) Z	- V Z	dig. linear axis dig. linear axis dig. linear axis
R2	C (axis des. 1) S1 S2	C S1 S2	- - -	C S1 S2	dig. rotary axis dig. main spindle dig. main spindle
F1	-	-	X1 (axis des. 2)	X	fictitious linear axis
F2	-	-	Y1 (axis des. 2)	Y	fictitious linear axis

When transformation is activated, the fictitious linear axes F1 and F2 instead of the main axes X and Y will participate in the interpolation. The Y axis becomes a secondary axis of the axis meaning V.

When transformation is switched off, the NC restores the original state.

Note: When the transformation function is employed, the process concerned may not contain an axis of the axis meaning V.

3.3 Setting the Parameter Values of the Fictitious Axes

The fictitious axes do not possess their own parameter records. For both fictitious axes, the NC employs the values that are stored for the linear main axis X:

Cxx.016	Max. fed rate	... [mm/min]
Cxx.017	Max. feed rate change w/o ramp	... [mm/min]
Cxx.018	Max. acceleration rate	... [mm/s^2]
Cxx.020	Jogging speed	... [mm/min]
Cxx.021	Jogging speed - rapid	... [mm/min]
Cxx.022	Parametric jogging distance	... [mm]
Cxx.023	Pos. travel limit	... [mm]
Cxx.024	Neg. travel limit	... [mm]

Thus, the individual velocity and acceleration values and the travel limits of both fictitious axes are identical.

3.4 Interface Signals of the Fictitious Axes

With active transformation, the axis-related interface signals of the associated real axes R1 and R2 are available for the fictitious axes F1 and F2.

3.5 Path Control Points for the Fictitious Axes

There are no path control points for the fictitious axes. The path control points always refer to the real axes and may also be interpreted during the execution of the transformation function.

4 Setting the Parameter Values of the Transformation Function

4.1 System Parameters

Entries in the system parameters are not required for the transformation function and for the fictitious axes F1 and F2.

The fictitious linear axes F1 and F2 do not occupy slots on the APR. As before, up to nine feed axes may exist within a process, irrespective of the fictitious axes. The maximum number of axes remains limited to 20.

Note: All axes that move in an interpolating way during transformation, must be on an APR. For a lathe, this means that the two real axes R1 (X) and R2 (C) and the Z axis must be accommodated on an APR.

4.2 Process Parameters

Whether or not the transformation function may be used during the machining process is defined in the process parameters.

Bxx.035 Cartesian/polar coordinate transformation possible
Yes / No

The default selection is „No“.

4.3 Axis Parameters

The axis designation of the fictitious axes F1 and F2 must be entered under the parameter:

Cxx.075 Axis designation 2 ... [ ]

of the associated real axes R1 and R2.

The user interface offers the axis parameter for

- analog and digital linear axes,
- analog and digital rotary axes, and for
- digital main spindles with rotary axis capability.

Like any other axis, the fictitious axes may have any name assigned. Like with real axes, each axis designation may only exist once within a process.

Irrespective of the axis meanings, the axis designations of the fictitious axes consist, like the axis designations of the other axes, of an axis letter and, optionally, of an axis index:

Axis designation = axis letter (+ axis index)

Axis letter $\in$ {X, Y, Z, U, V, W, A, B, C}

Axis index $\in$ {1, 2, 3}

If there is an axis with the axis meaning Y, a second axis designation must be entered for that axis, too (the axis designation 2 may be identical to the axis designation 1). During transformation, that axis may be programmed and moved using the second axis designation.

Cxx.076 Direction of polar coordinate transformation
0/1 [ ]

The axis parameter is used for reversing the direction of rotation when the transformation function is active. The default value of that axis parameter is 0.

The user interface shows the axis parameter for

- digital linear axes,
- digital rotary axes and
- digital main spindles with rotary axis capability.

Note: The transformation function is only available for digital drive combinations:

- digital main spindles with rotary axis capability with digital linear axis, and
- digital rotary axis (separate drive) with digital linear axis

5 NC Programming

5.1 Calling the Transformation

The transformation function forms a G code group, and has a modal effect.

G30 De-selection (power-on state)

G31 Transformation ON

When the transformation function is activated, the MT-CNC automatically triggers a changeover to rotary axis mode. For a lathe with a separate C axis drive, this means that the C axis drive is engaged during the transformation process.

To improve clarity, the G codes for activating and de-activating the transformation function should be programmed in a separate block.

Note: Prior to activating the transformation, the R1 axis must be moved to the positive section (R1>0).

5.2 NC Commands That Are Not Permitted During Transformation

The following list contains all functions that may not be programmed during transformation:

- Thread cutting 'G33'
- Zero shifts 'G50', 'G51', 'G52'
  (provided that shifts are programmed for R1 and R2)
- Tapping 'G63', 'G64', 'G65'
  (provided that the main spindle (that is allocated to R2) is addressed)
- Homing 'G74'
  (provided that homing is specified for the axes F1 and F2)
- Traveling to dead stop 'G75'
- Canceling all axis preloads 'G76'
- Speed limitation 'G92'
  (provided that the speed limitation is for the main spindle that is allocated to R2)
- Feed per revolution 'G95'
  (provided that the feed specification is for the main spindle that is allocated to R2)
- Constant surface speed 'G96',
- Spindle control commands 'M03', 'M04', 'M05', 'M13', 'M14', 'M19'
  (provided that a spindle-related auxiliary function is programmed for the main spindle that is allocated to R2)
- Axis transfer commands 'GAX', 'FAX'
  (provided that the commands have an effect on the axes F1, F2, R1 and R2)

All those functions will interrupt the execution and lead to an error message if they are invoked during the transformation.

5.3 Axis Programming

The fictitious axes F1 and F2 may only be programmed and moved when transformation (G31) is selected. During that time, the real axes R1 and R2, that participate in the transformation, may neither be programmed nor moved in manual mode.

Accordingly, the fictitious axes may neither be programmed nor moved in manual mode when transformation is de-selected.

5.4 Automatic Plane Selection

When the transformation function is switched on, the NC automatically selects the XY plane (G17). During transformation, the currently active working plane G17 appears in the status display.

After the transformation function has been de-selected, the NC automatically restores the default working plane that is specified in the process parameters.

5.5 Zero Offsets

Irrespective of the activity status of the transformation, the zero offset table continually shows all existing real and fictitious axes. The related zero offset values may be edited at any time.

Example

For the lathe in the example of Chapter 3.2, the zero offset table looks like this:

Axis	X/X1	Y/Y1	Z	C	Phi	Comment
.						
.						
G54	0.01	0.0	68.42	0.0	0.0	turning mode
G55	0.15	0.25	68.42	0.0	0.0	milling mode with
G56	0.0	0.0	0.0	0.0	0.0	Y transformation
G57	5.32	23.02	65.0	15.0	15.0	
.						
.						

The structure of the zero offset table depends on the existing axis meanings.

Axis with the same axis meaning share one column.

In our example, this means that the fictitious axis F1 with the axis designation X1 and the real axis R1 with the axis designation X form one column, while the fictitious axis F2 with the axis designation Y1 and the real axis Y form another column.

If there is no axis with the axis meaning Y (which can frequently be found with lathes), the fictitious axis F2 is in its own column.

During transformation, the entered values act on the related fictitious axes. If transformation is inactive, they act on the associated real axes. Accordingly, the values entered under the angle Phi causes the plane spanned by the fictitious axes to be rotated when transformation is active, and causes a rotation within the active working plane when transformation is inactive.

Note: Separate workpiece zero points (G54 through G59) should be used if transformation mode requires zero offsets.

When the transformation function is switched on and off, the NC sets the machine zero point G53, which de-activates all zero offsets.

As long as transformation is active, G50, G51, or G52 may not be used for programming zero offsets for the real axes R1 and R2. Any attempt of doing this will result in the NC generating an error message and aborting execution.

The NC responds in the same way if a zero offset is programmed for one of the fictitious axes F1 or F2 while transformation is switched off.

When the transformation function is active, G50 (absolute zero offset) and G51 (incremental zero offset) may, in addition to linear offsets, be used for performing rotations within the plane that is spanned by the fictitious axes.

5.6 Tool Corrections

When the transformation function is switched on and off, the NC de-activates tool length and tool radius correction.

Tool length and tool radius correction may already be active when transformation is switched on. Its operation is not influenced by the transformation function.

Note: Only tools of type 1 or 2 may be used during transformation.

If the utilization of a type 4 tool (angle-head tool) is absolutely necessary, the tool length correction values L1 and L2 must be taken into account in geometry programming. A value 0 must be entered for the corresponding tool length correction values L1 and L2 of the tool.

5.7 Diameter Programming

When the transformation function is switched on, the NC automatically selects radius programming (G15).

When the transformation function is switched off, the NC restores the programming type that has been stored in the process parameters: G15 programming type (radius programming) or G16 (diameter programming).

Note: If G16 (diameter programming) is selected during transformation, the NC interprets all position values of the fictitious axis F1 as diameter specifications.

5.8 Axis Transfer

Neither the fictitious axes F1 and F2 nor the real axis R2 can be transferred between the processes.

5.9 Reference Spindle for Transformation

Within a given process, the transformation function can only be active once. It may be related, however, to spindle 1, 2 or 3, or to the associated rotary axes (R2) with the axis meanings A, B or C.

The associated rotary axes may not be declared as auxiliary axes (axis meaning U, V or W).

Provided it is not yet the reference spindle, the reference spindle that is valid for transformation may be selected via the SPC (spindle selection for

Cartesian/polar transformation) command before or during transformation.

Using the SPF command, the reference spindle for feed programming during tapping (G63, G64, G65) and for speed limitation (G92) may be switched over even when the transformation function is active.

6 Exceptions

6.1 Power-On State

The transformation function is always inactive (G30) when the controller is switched on.

6.2 Control-Reset

Each reset de-activates the transformation function (G30).

6.3 Changing the Mode

The NC does not reset the transformation function when the mode is changed or during jogging in manual mode.

6.4 Reverse

A reverse does not have any effect on the transformation function. Merely a homing of the fictitious axes F1 and F2 interrupts execution and causes an error message to be issued (with active or inactive transformation).

The real axes R1 and R2 may only be homed when transformation is inactive.

6.5 Process Enabling Signal

When the process enabling signal is switched off, the NC shows the same behavior for active and for inactive transformation.

6.6 Axis Enabling Signal

The NC interprets the axis enabling signal of the real axes in manual mode only.

6.7 Feed and Spindle Override

Feed override always acts upon the axes that participate in path interpolation. (and thus indirectly upon the real axes R1 and R2), and on the other axes that participate in interpolation.

Like in C axis mode, spindle override is not taken into account.

7 Interface Signals

PxxSTRANS

0: Transformation is not active
1: Transformation is active

The „transformation is active“ status signal tells the SPS whether or not the transformation function is currently active in the NC.

The NC updates the status signal in all modes.

8 Typical NC Program

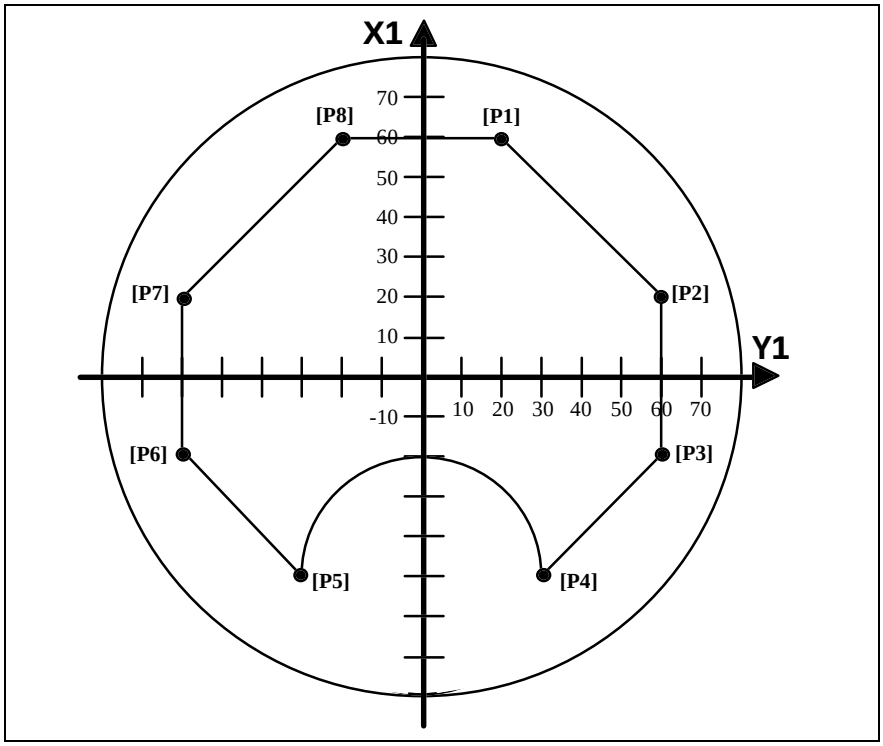

Fig. 8-1: Facing with transformation

NC program

```
T12 BSR .M6                     ;Changing driven tool
BSR .M89                        ;Engaging driven tool
S2 3500 M203                    ;Driven tool ON
G00 Z10
X50 C0                          ;Basic position for changeover
G31                             ;Switch on transformation
G54 G00 G90 G17 G06 G08 G48     ;Initial position
X1 60 Y1 20                     ;[P1] Machining starting point
G01 Z-0.5 F500                  ;Infeed Z axis
G42 X1 20 Y1 60 F400            ;[P2] 1st straight line
X1 -20                          ;[P3] 2nd straight line
X1 -50 Y1 30                    ;[P4] 3rd straight line
G03 X1 -50 Y1 -30 I-50 J0       ;[P5] CCW semi circle
G01 X1 -20 Y1 -60               ;[P6] 4th straight line
X1 20                           ;[P7] 5th straight line
X1 60 Y1 -20                    ;[P8] 6th straight line
Y1 20                           ;[P1] 7th straight line
G00 Z10                         ;Z axis to safety distance
G30                             ;De-selecting Transformation
G54 G48 G00 X130                ;Initial position
Z200                            ;Withdraw Z axis
RET                             ;End of program
```

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