Application description • 12/2013

CYCLE996 example part indexing table

SINUMERIK 828D, 840D sl

http://support.automation.siemens.com/WW/view/en/78452068

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1 Determining the swivel data set

1.1 Position of the part indexing table

In order to obtain high-quality workpieces using multi-axis machining, it is essential that the rotary axes of the machine are precisely aligned with respect to one another. As a consequence, the kinematics of the rotary axes, and therefore also the vectors in the swiveling data set of the machine, must be measured. This is possible using the CYCLE996 kinematic measuring cycle. The previous costs for the technology required, and the associated time, no longer applies. The cycle automatically measures the rotary axis vectors using a calibration ball (sphere) and a calibrated probe.

CYCLE996 can also be applied in a modified form, for example on a 3-axis milling machine. In the actual example, on a machine table of a 3-axis milling machine, a part indexing table is mounted as rotary axis that rotates around the X axis (Fig. 1-1).

The precise position of the part indexing table is measured and the measured data are entered into the swivel data set of the machine using CYCLE996.

Design of a part indexing table on a three-axis milling machine

The following diagram provides an overview of the specific design of the part indexing table

Fig. 1-1 Design of a part indexing table

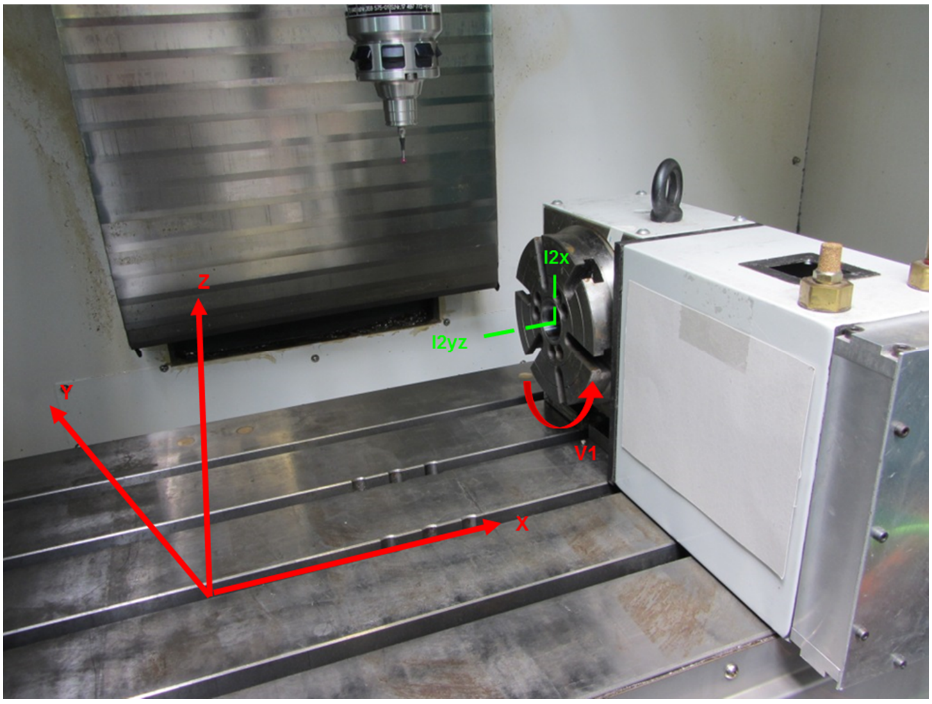


Table 1-1 Alignment of the part indexing table

No.	Vectors	Designation
1.	I2yz	Center of rotation of the part indexing table
2.	I2x	Table reference surface
3.	V1	Direction of rotation of the rotary axis vector

2 Measuring cycle "CYCLE996"

2.1 Overview of the overall solution

The task of the CYCLE996 measuring cycle is to simplify the procedure when determining geometrical vectors. The machine kinematics are defined by the geometrical vectors. For measurement purposes, a calibration sphere is mounted on the part indexing table. The principle of this measurement version is that three swivel positions of the calibration sphere are measured for each rotary axes using a probe. The axis vectors in this plane can be calculated from this data. The part indexing table (Fig. 2-1) has a rotary axis; as a consequence, only three swivel positions are required when making the measurement. The kinematics are automatically calculated immediately after the rotary axis vectors have been measured.

Schematic diagram

The following diagram shows the active measurement operation:

Fig. 2-2-1 Part indexing table as rotary axis with calibration sphere and workpiece probe

Advantages of this solution

The solution based on the CYCLE996 presented here has the following advantages:

- Detailed knowledge about the mechanical system of the machine is not necessary
- Measurement is realized without dimension drawings and design drawings of the machine
- The swivel positions of the calibrations sphere do not have to be manually approached
- Less time is required when determining the axis vectors, by up to one day

Typical applicationsfor CYCLE996

The CYCLE996 measuring cycle allows the relevant parameters of the swivel data sets to be quickly and easily determined, which are required for the kinematic transformation. The following types of application are possible:

Table 2-1 Applying the data for the kinematic transformation

	Redetermining swivel data sets	Checking swivel data sets
1.	Commissioning the machine	Service after a collision
2.	Using swivel-mounted workholders as TCARR	Checking the kinematics during the machining process

Using CYCLE996, kinematics with NC-controlled rotary axes can be measured just the same as for manual rotary axes. Manual rotary axes involve clamping equipment that can be swiveled or adjustable indexing tables. The part indexing table in this particular example uses the tool carrier function (TCARR), which is a measure for the tool length compensation.
In conjunction with the CYCLE800 swivel cycle, it is possible to initiate a rotation without having to program the part indexing table, a complex undertaking.
After each measurement position the part indexing table rotates to the next measurement position. It should be noted that the parameters of the swivel data set for CYCLE800 must be approximately known and entered.

2.2 Preconditions for using CYCLE996

The following preconditions for using CYCLE996 at the part indexing table must be fulfilled:

- A calibrated workpiece probe must be available
- A mounted calibration sphere for CYCLE996
- Right angled, referenced basic geometry of the machine (right angle refers to the workpiece spindle and should be preferably checked using a test mandrel)
- The table reference surface must be mechanically aligned and in parallel with machine axes Y and Z.
- The part indexing table must be aligned to be in parallel to the axes
- Defined traversing direction of the axes involved in the transformation according to ISO 841-2001 and/or DIN 66217
- Commissioning the rotary axis of the part indexing table
- Setting up the machine data for Cycle800
- Commissioning the swivel data set with a rotary axis MD20196 ($MC_TOCAR_ROTAX_MODE changing from 0 to a value of 1)
- Setting up an orientated tool carrier MD18088 ($MN_MM_NUM_TOOL_CARRIER > 0)

3 Commissioning CYCLE996

The following must have been performed to measure the rotary axis to prepare the part indexing table:

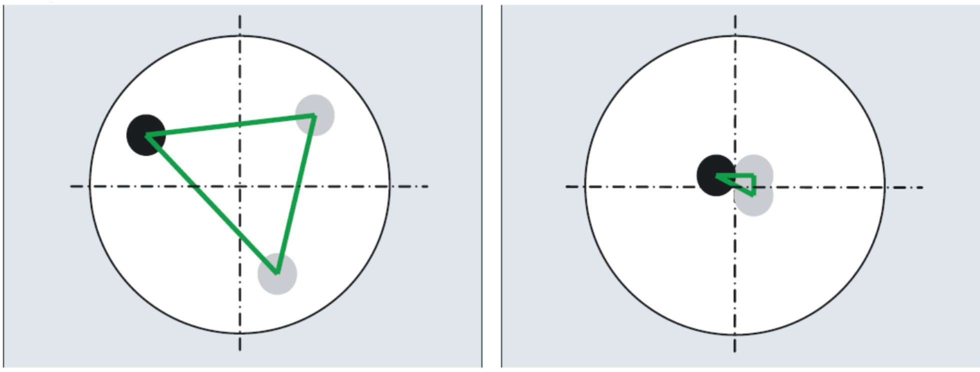
- The calibration sphere must have been mounted on the part indexing table
- The three sphere positions of the rotary axis of the part indexing table to be measured must have been defined and approached
- The three sphere positions with measuring probe must have been defined and approached using linear motion
- Using CYCLE996, scan all three sphere positions of the calibration sphere with the probe.

3.1 Mounting the calibration sphere on the part indexing table

The calibration sphere must be mounted on the part indexing table of the machine. It must be ensured that the mounted calibration sphere can be approached and passed around with the probe in all three selected measurement positions without collisions occurring. Considering the need to avoid collisions, the calibration sphere should be mounted as far as possible from the center of rotation of the rotary axis that is to be measured.

If the three measurement positions result in too small a triangle, this will negatively affect the accuracy of the procedure:

Fig. 3-3-1 Mounting the calibration sphere



Calibration sphere mounted sufficiently far away from the center of rotation, large triangle can be obtained

Calibration sphere mounted to close to the center of rotation, triangle formed too small

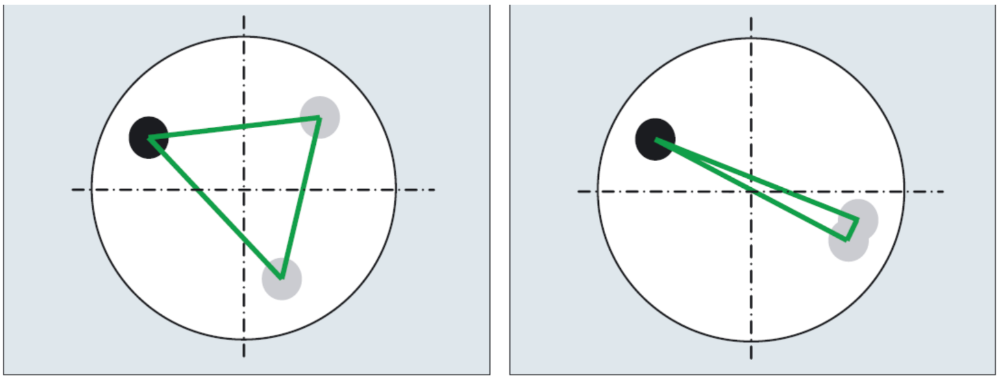
Note

> While measuring a rotary axis, the mechanical attachment of the calibration sphere must not be changed.

3.2 Defining the rotary axis position of the part indexing table

Three measurement positions (sphere positions) must be defined for the part indexing table with a rotary axis. Please note that the positions of the sphere in space (resulting from the three defined rotary axis positions) should represent the largest triangle possible.

Fig. 3-2 the correct rotary axis position



Rotary axis positions sufficiently far away from one another, large triangle is formed	Rotary axis positions poorly selected, triangle formed too small

Note The calculated angle of the rotary axis angular segment is monitored in parameter TVL. Angles of < 20 degrees can cause inaccuracies when calculating the kinematics.

3.3 Approaching the sphere position

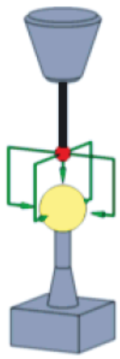
Initially, the probe must be positioned above the calibration sphere at each of the three rotary axis measurement positions defined by the user. The user must define the measurement positions.

To do this, the coordinates of the measurement positions must be manually determined using an active probe. When selecting the start point, it must be ensured that the start position of the probe lines up with the center point of the calibration sphere. A possible starting point for the probe above the calibration sphere is shown in the following Fig. 3-3.

Note The position must only be approached by traversing the linear axes

(X, Y, Z).

Fig. 3-3 Starting point of the calibration sphere

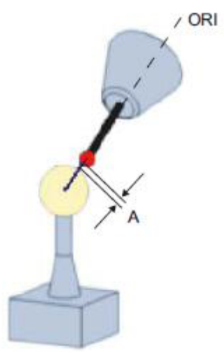


Starting point directly above
The calibration sphere

3.4 The starting position

The probe must be prepositioned in the direction of the tool orientation (ORI) above the highest point of the calibration sphere (probe aligned with sphere center point). The distance (A) to the calibration sphere after approaching the starting position should correspond to the measuring path parameter (DFA). The measuring path (DFA) can be found in the input screen form for the first to third measurement of CYCLE996. In practice, the measuring path (DFA) is the radius of the calibration sphere. In the current example, this value is 5 mm.

Fig. 3-4 Starting position



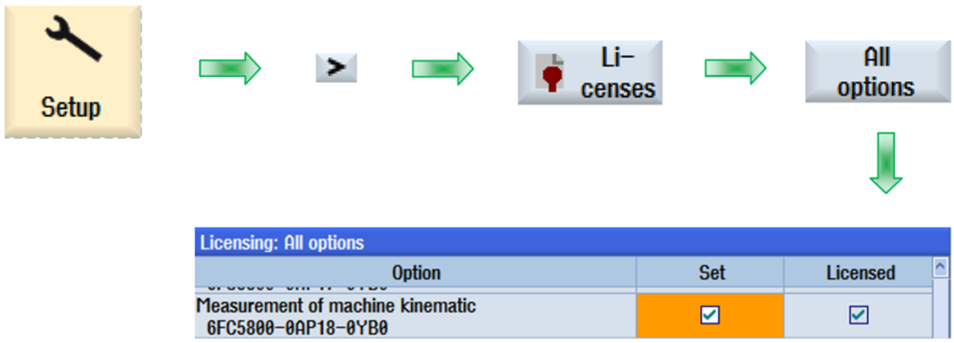
4 Using CYCLE996

4.1 Preparation

4.1.1 Setting the license

The "Measure kinematics" option must be set and licensed when making measurements using CYCLE996.

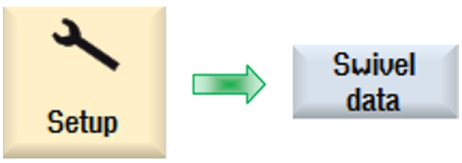
Figure 4-1 Instruction to activate the "Measure kinematics" option



4.1.2 Setting the swivel data

When starting CYCLE996 a swivel data set must be parameterized with the basic data of the kinematic type being used. This data can be found under the point, Commissioning:

Fig. 4-2 Navigation to the swivel data set



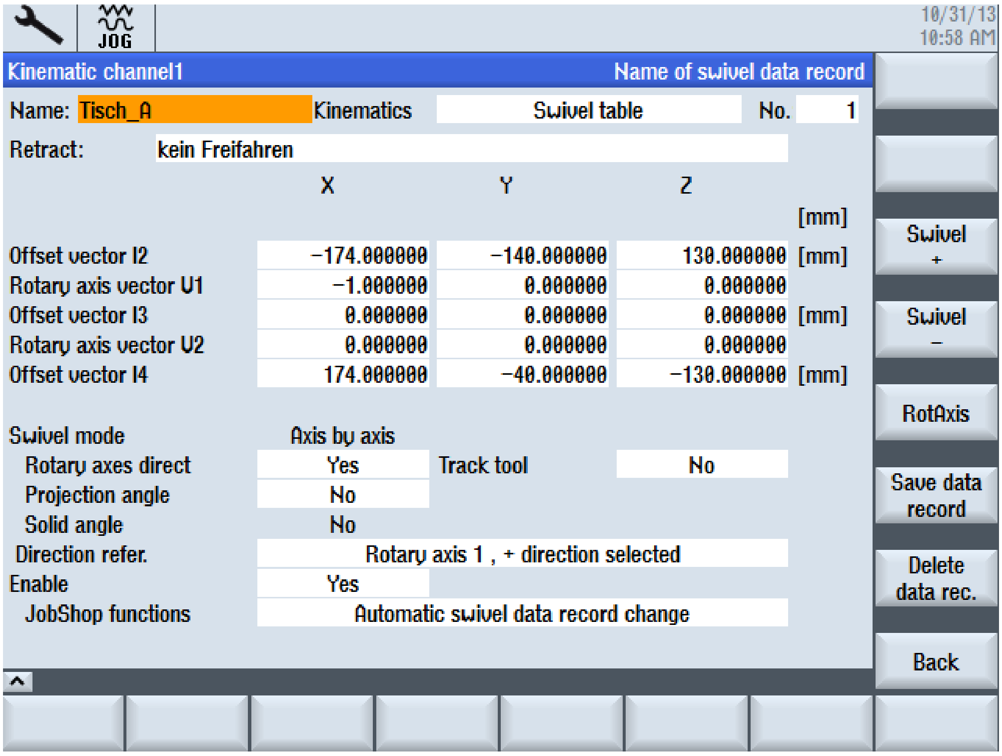
The probe is roughly positioned in front of the center of rotation of the part indexing table and the coordinates are entered in the MCS for the Y and Z axis in vector I2 of the swivel data set. The probe is then traversed over the part indexing table until the X coordinates of the probe coincide with the X coordinates of the table reference surface. These X coordinates should also be entered into swivel data set I2 in the MCS. Fig. 4-3 shows how the offset and rotary axis vector data should be entered.

Offset and rotary axis vectors

Offset vectors always contain three components, which represent the reference to the machine axes (X, Y, Z). Depending on the selected kinematic type (T, P, M), the vector chain must always be closed with the third vector. Offset vectors I1 to I4 always refer to the non-swiveled state of the rotary axes (machine kinematics basic setting).

The offset vectors do not have to be aligned to the center of rotation of the rotary axis of the part indexing table. The important thing is that they point to a point on the direction of rotation. The sign of the offset vectors (I1 to I4) and the rotary axis vectors (V1) are obtained from the specifications of the axis directions according to DIN/ISO (right-hand rule). In the case of kinematics that move the workpiece (rotary table), the motion of the workpiece relative to the tool must be taken into account.

Fig. 4-3 Entering vectors into the swivel data set

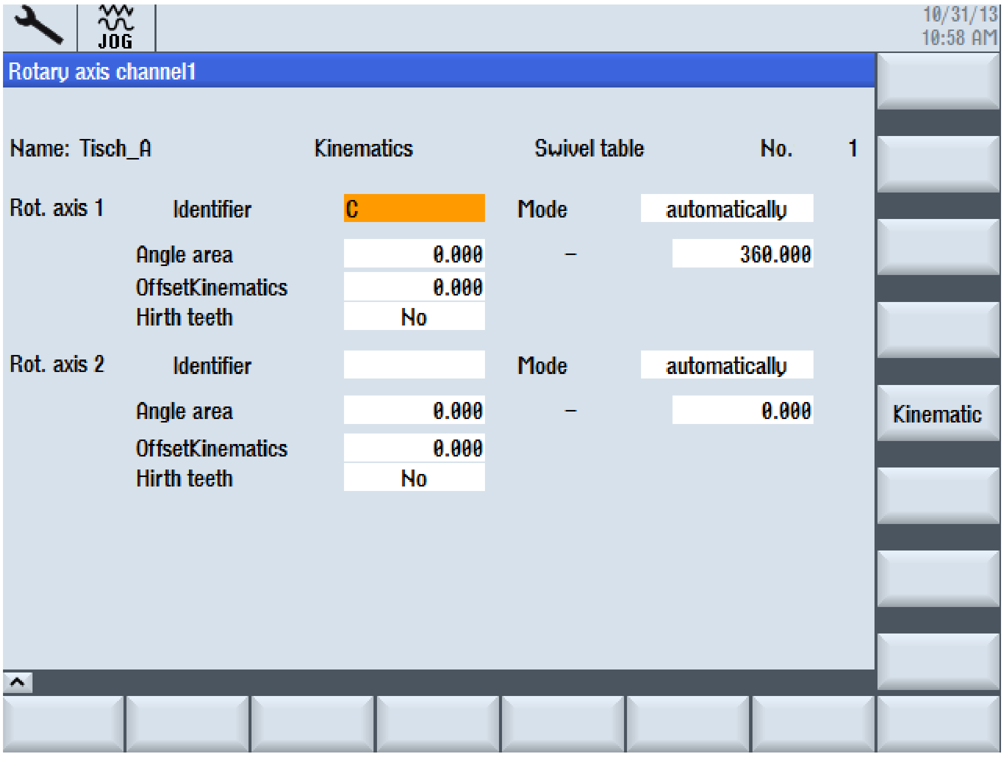


The value of rotary axis vector V1=-1 defines the P type kinematics of the swivel data set. Additional important input parameters are all of those below the swivel mode in the input screen form "Name of the swivel data set". Offset vectors I2 and I4 are required to subsequently rotate the part indexing table, using CYCLE800.

As it only involves a rotary axis, the second axis does not have an axis name (Fig. 4-4). Rotary axis C is inclined in the machine by 90°:

- First rotary axis C corresponds to the part indexing table
- The second rotary axis does not have an axis name

Fig. 4-4 Entering the rotary axis data



4.2 Measuring kinematics

CYCLE996 must be called four times for the complete measurement and calculation of the vectors of the specified rotary axis of the part indexing table. Once the probe has been positioned in accordance with user specifications above the sphere, either manually or by the part program (starting point of CYCLE996), the calibration sphere is scanned by calling CYCLE996 and the current set sphere position is measured.

Between calls, the user must reposition the rotary axis to be measured. This is assigned using CYCLE800.

The linear axes are positioned at the measuring position P1(C=0°), P2 (C=120°), P3 (C=240°). The first to third measurements are called using the softkeys in the input screen form of CYCLE996. The vectors of the measured rotary axis are called with the "Calculate" call immediately after the third measurement.

The objective of the following steps is to correctly enter the parameters, taking into account the special geometrical issues of the mounted indexing table.

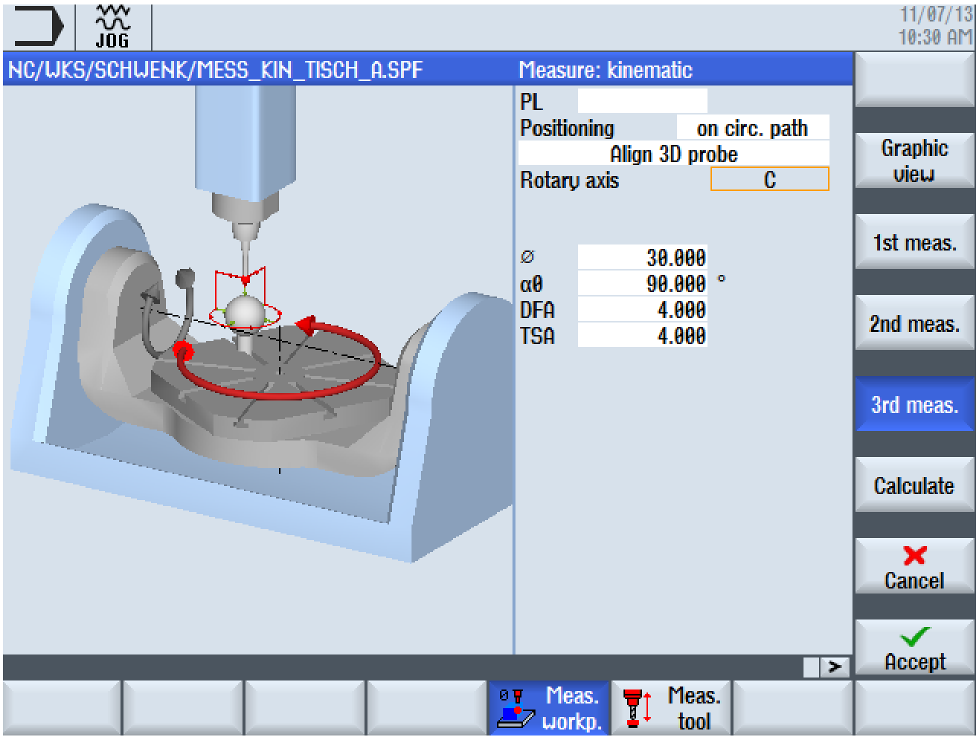
Preparation

The workpiece probe has been loaded and a calibrated; this means that the radius and the tool length have been compensated. The calibration sphere is mounted on the part indexing table, and this is at position C=0°. Once these conditions have been fulfilled, it makes sense to start to enter the parameters into the kinematics screen form.

Fig. 4-5 Navigation to the input screen form CYCLE996

4.2.1 First measurement

Fig. 4-6 First CYCLE996 measurement



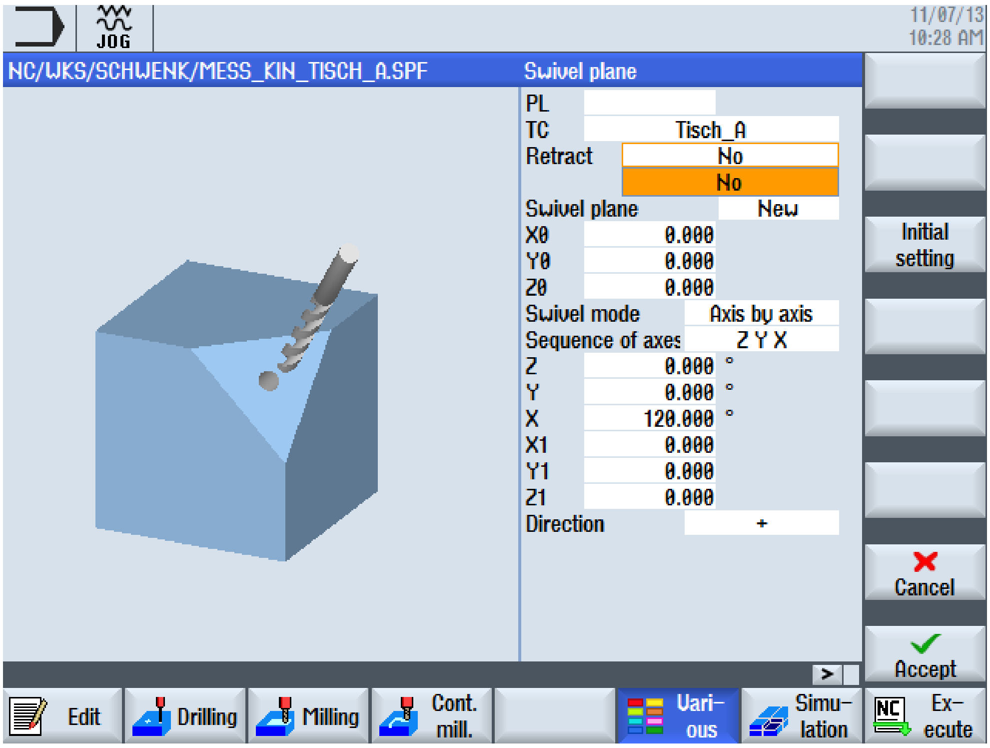
It should be noted, that for this measurement version, the "Positioning on the circular path" and the alignment of the "3D probe" are selected.

Fig. 4-7 first CYCLE996 measurement at the part indexing table

The part indexing table is swiveled through 120° around the Z axis in the input screen form. For the actual machine configuration this corresponds to a 120° rotation around the X axis. This motion is executed with swivel data cycle 800.

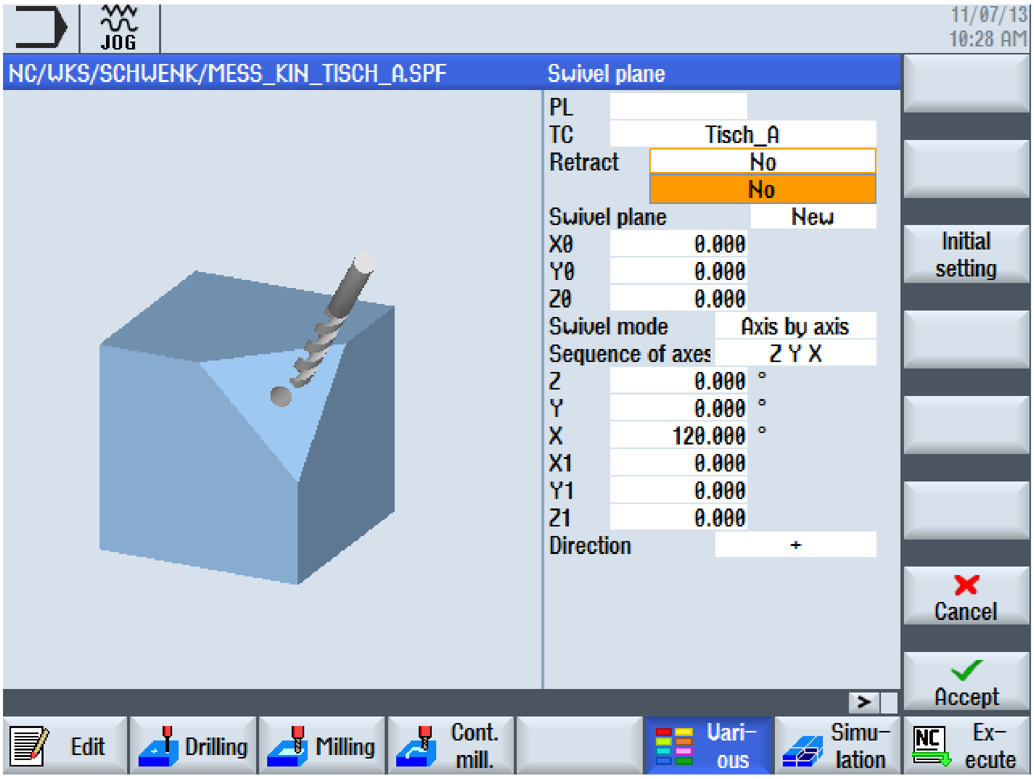
Fig. 4-8 Navigation to the CYCLE800 swivel cycle

Fig. 4-9 Input screen form of the CYCLE800



4.2.2 Second measurement

Fig. 4-10 Second CYCLE996 measurement



For the measurement, and also for the third measurement, the probe must be pre-positioned at the upper side of the calibration sphere.

Fig. 4-11 Second CYCLE996 measurement at the part indexing table

4.2.3 Third measurement

In order that the probe can navigate at the shaft of the calibration sphere during the measurement, before the third measurement is performed, a starting angle of 90° should be set.

Fig. 4-12 Third CYCLE996 measurement

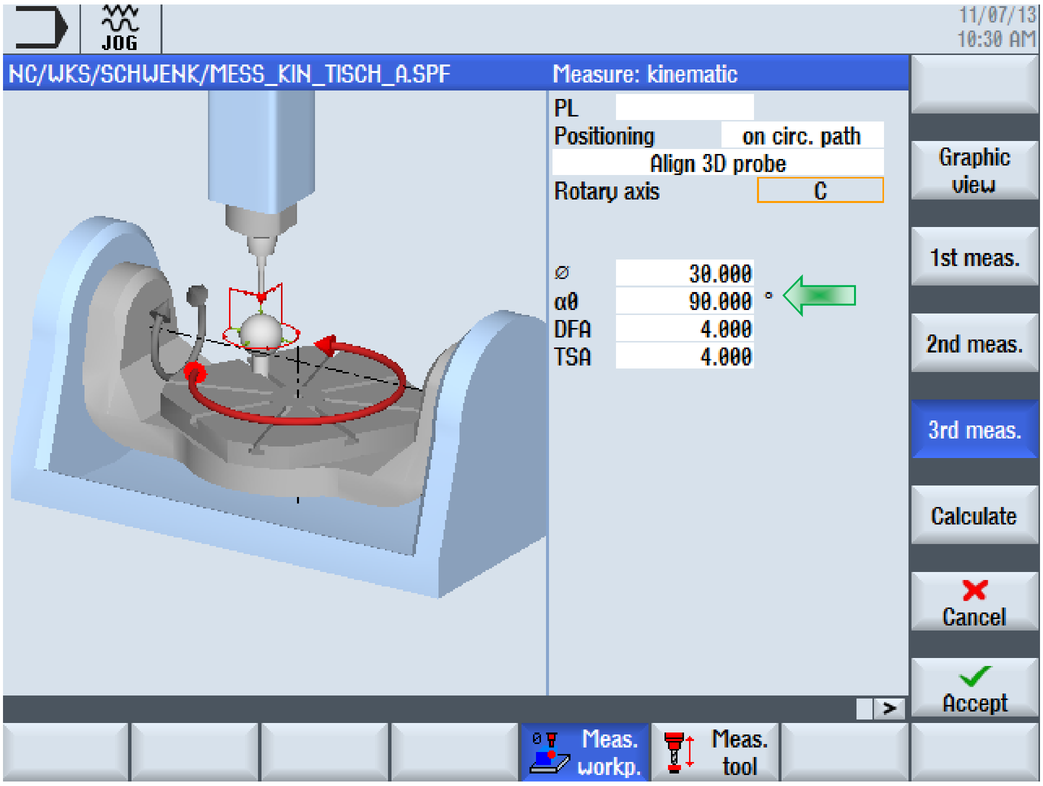
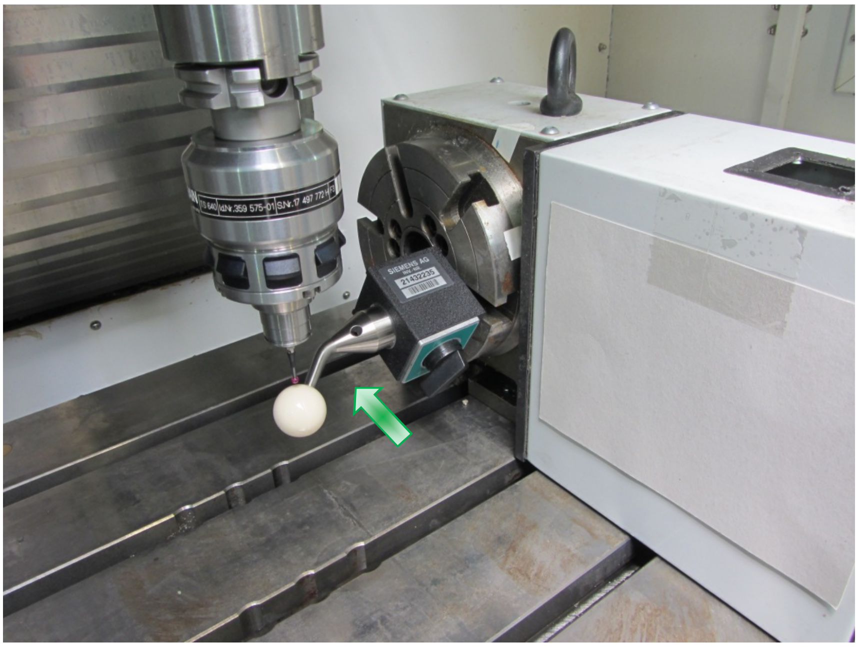


Fig. 4-13 Third CYCLE996 measurement at the part indexing table



Before the offset vectors can be calculated, the
X position of the table reference surface must be determined.

Fig. 4-74 Determining the table reference surface

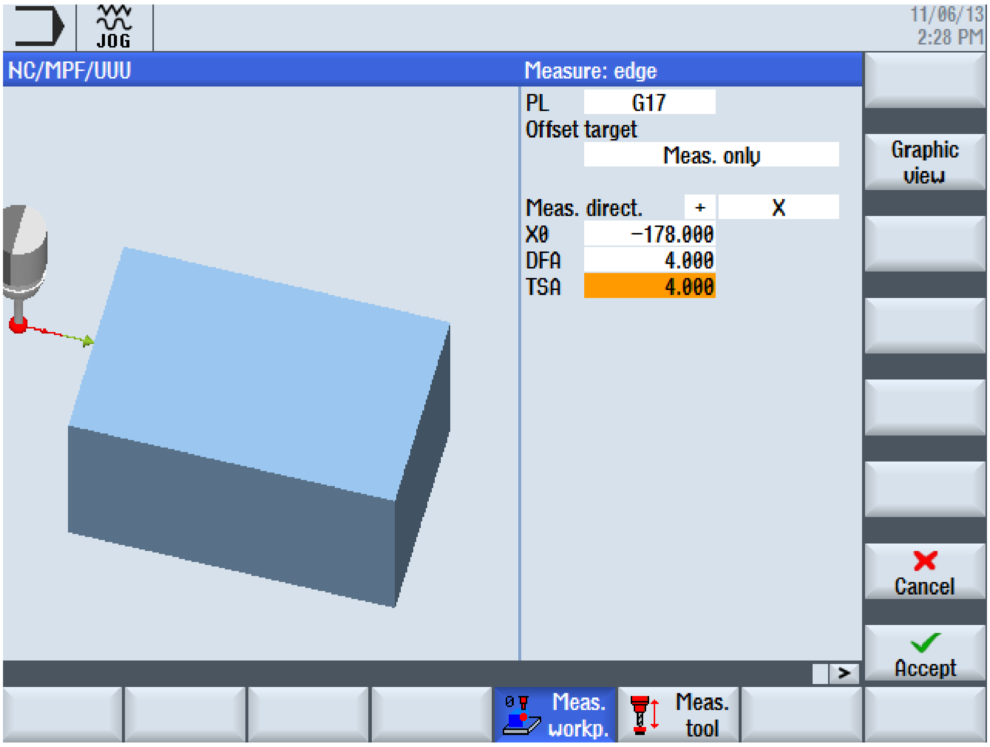
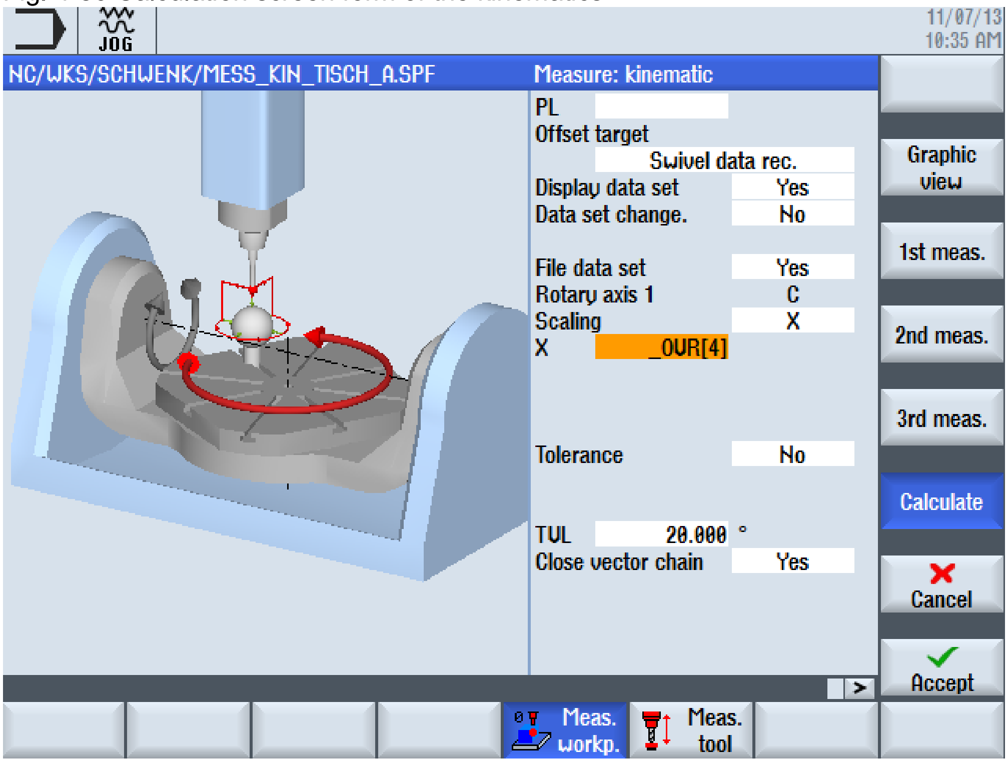


Fig. 4-15 Determining the table reference surface at the part indexing table

4.2.4 Calculate

When calculating the kinematics, the reference point of the X axis is normalized to the table reference surface. Parameter _OVR[4] of the last measurement is used for this purpose. Complete the calculation screen form as follows:

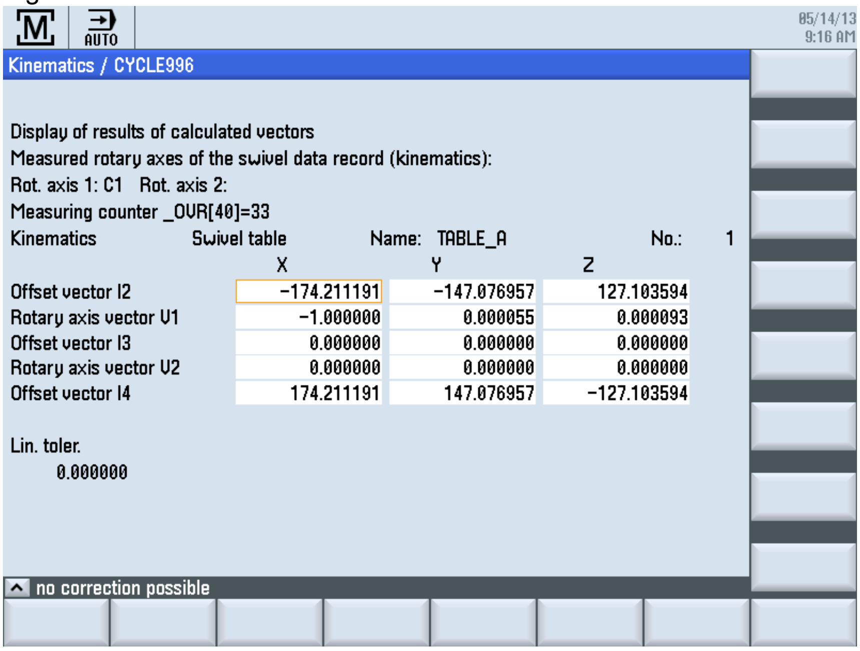
Fig. 4-86 Calculation screen form of the kinematics



Result display

A deviation in V1y and V1z can be seen in vector V1. This deviation indicates when the part indexing table has been correctly mechanically aligned. Measured vector V1 is not automatically transferred into the swivel data set.

Fig. 4-17 Result of the calculated kinematics



If the "Calculate kinematics" selection is active, a result display can be selected in the screen form for CYCLE996 as follows:

- No – the results are not displayed after the calculation has been completed.
- Yes – after the calculation the individual values are displayed and can be edited.
- Yes, can be edited – the result parameters can be modified

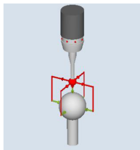
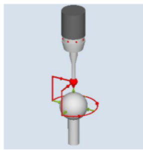
4.3 Measuring program with CYCLE996

```
G55 G17 G40                                                  ; Starting point

$SCS_MEA_RESULT_DISPLAY=0                                    ; Display measurement
                                                               result

GOTOF _NUR_CALC
MHOME ("C")

T="3D_MESSTASTER"                                            ; The 3-D probe
M6                                                             is loaded


1st MEASUREMENT
G0 X0 Y0
G0 Z20                                                       ;Radius of the measuring
                                                              sphere +
                                                              5mm tolerance

CYCLE996(10201,1,1,30,0,0,0,0,0,0,0,20,4,4,1,,1,)            ;1. measurement

CYCLE800(0,"Table_A",200000,27,0,0,0,0,0,120,0,0,0,1,100,0)  ;rotation through 120°

2nd MEASUREMENT
G0 X0 Y0
G0 Z20                                                       ;Radius of the sphere +
                                                              5mm tolerance

CYCLE996(10202,1,1,30,0,0,0,0,0,0,0,20,4,4,1,,1,)            ; 2. measurement

CYCLE800(0,"Table_A",200000,27,0,0,0,0,0,240,0,0,0,1,100,0)  ; rotation through
                                                               additional 120°

3rd MEASUREMENT
G0 X0 Y0
G0 Z20                                                       ; Rotation through
                                                               additional 120°


CYCLE996(10203,1,1,30,90,0,0,0,0,0,0,20,4,4,1,,1,)           ; 3. measurement

CYCLE800(0,"Table_A",200000,27,0,0,0,0,0,0,0,0,0,1,100,0)    ; Rotation through
                                                               additional 120°

EDGE MEASUREMENT
CYCLE978(0,,,1,-178,4,4,1,1,1,"",,0,1.01,1.01,-1.01,,,,,1,1)  ; Measurement of the
                                                             table reference surface

CYCLE996(10101200,1,1,30,0,0,0,_OVR[4],0,0,0,20,4,4,1,,0,100) ;calculation

M30                                                          ; End of program
```

5 Selectable parameters

5.1 Parameters of the CYCLE996 measurement

Table 5-1 Parameters of the first up to the third measurement

No.	Parameter	Selection/input
3.	**PL**	Measuring plane (G17 - G19)
4.	**Positioning**	Traverse around sphere: • in parallel with the axis • on a circular path  
5.	**Align probe** (only for positioning) "along the circular path")	Always align probe in the same contact direction: **(only for positioning "On circular path")** • Yes • No
6.	Rotary axis 1	Name of rotary axis 1 of the swivel data set
7.	Rotary axis angle 1	Rotary axis angle during the measurement
8.	Rotary axis 2	Name of rotary axis 2 of the swivel data set
9.	Rotary axis angle 2	Rotary axis angle during the measurement
10.	ø	Sphere diameter
11.	α0	Starting angle **(only for "Positioning on circular path")**
12.	**DFA**	Measurement path
13.	**TSA**	Safe area

5.2 Parameters of the CYCLE996 calculation

Table 5-2 Calculation parameters

No.	Parameter	Description			Unit
14.	**PL**	Measuring plane (G17 - G19)			-
15.	**Correction target**	Only measuring (only calculate vectors)	Swivel data set (calculate vectors and save to swivel data set)		-
16.	Display data set	Yes/No	No	Yes	-
17.	Data set can be change	-	-	Yes/No	-
18.	Confirm the change	-	Yes/No	-	-
19.	Save data set	Data set is saved in a protocol file			-
20.	**Rotary axis 1**	Name of rotary axis 1 of the swivel data set			-
21.	**Normalization**	• No (without normalization) • X (Normalization in the X axis) • Y (Normalization in the Y axis) • Z (Normalization in the Z axis)			-
22.	Value input	Position value for normalizing			mm
23.	**Tolerance**	Use dimensional tolerance • yes • no			-
24.	TLIN	Max. tolerance of the offset vectors			mm
25.	TROT	Max. tolerance of the rotary axis vectors			Degrees
26.	TVL	Limit value for distortion of the triangle			Degrees
27.	**Close vector chain**	• yes • no			-

5.2.1 Correction target

In the "Calculate kinematics" screen form, in the "Correction target" field, for the vectors it can be set as to whether the vectors should be calculated (only measuring) – or whether the calculated factors should be saved in the swivel data set. Before saving, the user can decide whether the calculated swivel data set should be displayed and changed. If the calculated swivel data set should not be displayed, the user can decide whether the swivel data set should be immediately overwritten. In all other cases, before saving the swivel data set, the operator is prompted to make a selection.

Table 5-3 Display options in the "Calculate kinematics" screen form

Parameter	Measuring only		Swivel data set	
Display data set	Yes	No	No	Yes
Data set can be edited	-	-	-	Yes/No
Confirm the change	-	-	Yes/No	-

5.2.2 Tolerance limits

Activating tolerance limits when parameterizing CYCLE996 (compare output values and calculated values), allows conclusions to be drawn as regards unusual changes in the mechanical kinematic chain. The unintentional automatic overwriting of output values can be avoided by adjusting the tolerance limits.

CAUTION

The rotary axis vectors V1/V2 (orientation of the rotary axes) are never automatically overwritten.

Primarily, the calculated rotary axis vectors enable an assessment to be made regarding the mechanical desired/actual state of the kinematics. Depending on the particular kinematics configuration, even the smallest and corrected deviations in the position of the rotary axis vectors can result in large compensating movements.

6 Contact person

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7 History

Table 7-1

Version	Date	Revision
V1.0	12/2013	First Edition