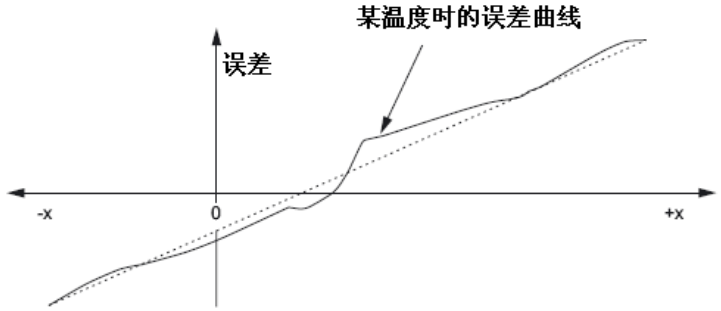
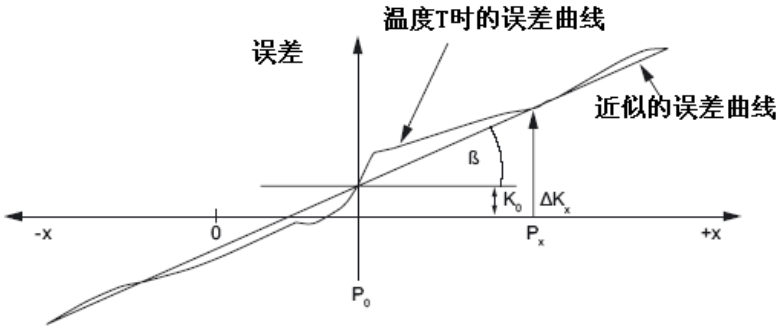
温度补偿

在机床运行中，环境温度变化或因电机等发热，热量会传导到机械部件上，可能会导致机械精度发生变化，进而影响到工件最后的精度。
温度补偿的原理比较简单，下图是测量的是某环境温度下，X 轴的误差曲线。



误差曲线接近于线性，因此将其按线性处理（非线性的误差对精度的影响可忽略。）



$\Delta K_x = K_0(T) + \tan\beta(T) * (P_x - P_0)$

ΔK_x --X 轴在位置 P_x 时的温度补偿值

K_0 --轴在参考位置时的温度补偿值

P_x --轴的实际位置

P_0 --轴的参考位置

$\tan\beta$ --位置误差近似曲线的斜率

	说明	对应参数
ΔK_x	X 轴在位置 P_x 时的温度补偿值	
K_0	轴在参考位置时的温度补偿值	SD43900 $SA_TEMP_COMP_ABS_VALUE
P_x	轴的实际位置	
P_0	轴的参考位置	SD43920 $SA_TEMP_COMP_REF_POSITION
$\tan\beta$	位置误差近似曲线的斜率	SD43910 $SA_TEMP_COMP_SLOPE

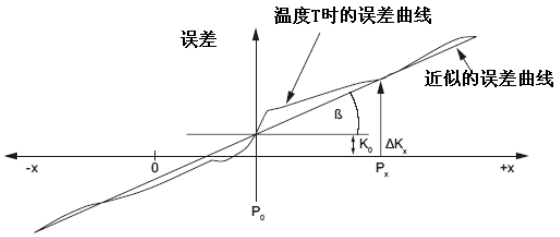
激活温度补偿，设置MD32750 $MA_TEMP_COMP_TYPE

MD32750	含义	相关参数
=0	没有温度补偿	
位 0=1	位置无关的温度补偿	SD43900 $SA_TEMP_COMP_ABS_VALUE
位 1=1	位置相关的温度补偿	SD43920 $SA_TEMP_COMP_REF_POSITION SD43910 $SA_TEMP_COMP_SLOPE
位 2=1	温度补偿到刀具方向	MD20390 $MC_TOOL_TEMP_COMP_ON

注意： 温度补偿在轴回参考点后才生效

不同温度下的曲线不同，可通过 PLC 调用 FB3 去修改上述参数。

实验：



	说明	对应参数
ΔK_x	X 轴在位置 P_x 时的温度补偿值	
K_0	轴在参考位置时的温度补偿值	SD43900 $SA_TEMP_COMP_ABS_VALUE=0.1
P_x	轴的实际位置	
P_0	轴的参考位置	SD43920 $SA_TEMP_COMP_REF_POSITION=10
$\tan\beta$	位置误差近似曲线的斜率	SD43910 $SA_TEMP_COMP_SLOPE=0.0001

实验一：设置 MD32750=1H

X 轴回零后，服务画面显示，补偿值=0.1：

Service axis/spindle X1 1

	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	1.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	-0.100	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	-0.100	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.100	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

X 轴走到任意位置，服务画面显示，补偿值=0.1：

Service axis/spindle X1 1

	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	0.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	608.156	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	608.156	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.100	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

由上面两图可以看出，当 MD32750=1H 时，温度补偿值为一个固定值。因此相关的参数只有 SD43900 $SA_TEMP_COMP_ABS_VALUE。

实验二：设置 MD32750=2H

X 轴回零后，，根据计算公式，补偿值=0.0001*(0-10)=-0.001

服务画面显示，补偿值=-0.001mm：

Service axis/spindle X1 1

	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	1.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	0.001	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	0.001	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	-0.001	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

X 移动到 10mm 时，根据计算公式，补偿值=0.0001*(10-10)=0

服务画面显示，补偿值=0mm：

Service axis/spindle X1 1

	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	1.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	10.000	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	10.000	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.000	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

X 移动到 50mm 时，根据计算公式，补偿值=0.0001*(50-10)=0.004

服务画面显示，补偿值=0.004mm：

Service axis/spindle X1 1

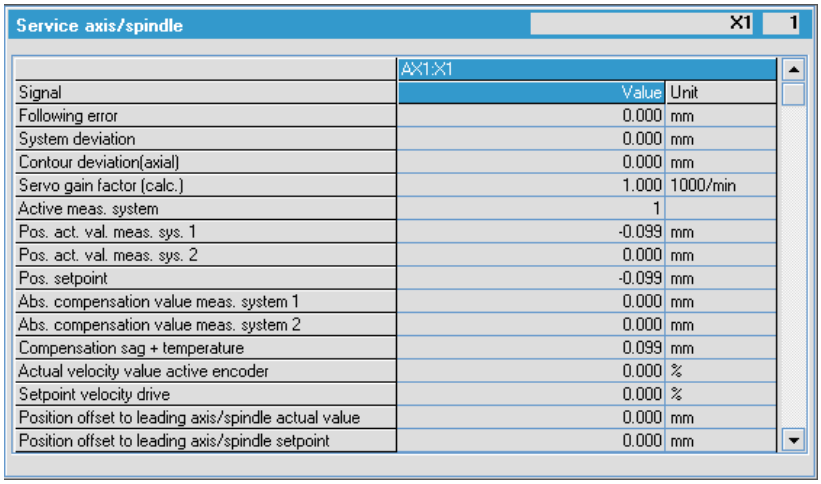
	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	1.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	49.996	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	49.996	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.004	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

由上面三图可以看出，当MD32750=2H时，温度补偿值为一个过零点的线性变化值。因此相关的参数有SD43920 $SA_TEMP_COMP_REF_POSITION和SD43910 $SA_TEMP_COMP_SLOPE

实验三：设置 MD32750=3H

X 轴回零后，，根据计算公式，补偿值=0.1+0.0001*(0-10)=0.099

服务画面显示，补偿值=0.099mm：

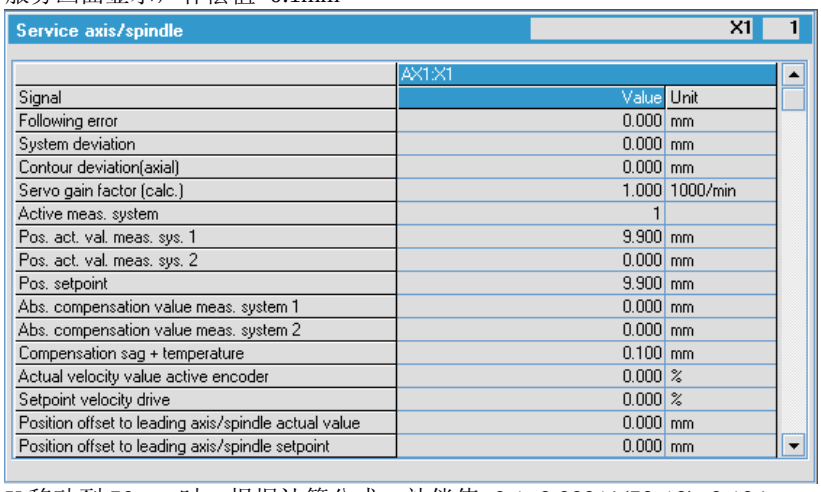


Service axis/spindle X1 1

	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	1.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	-0.099	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	-0.099	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.099	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

X 移动到 10mm 时，根据计算公式，补偿值=0.1+0.0001*(10-10)=0.1

服务画面显示，补偿值=0.1mm

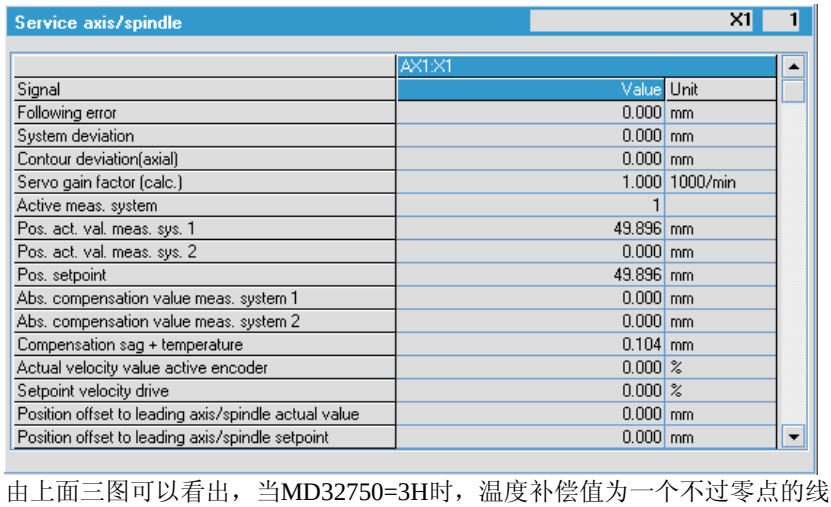


Service axis/spindle X1 1

	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	1.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	9.900	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	9.900	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.100	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

X 移动到 50mm 时，根据计算公式，补偿值=0.1+0.0001*(50-10)=0.104

服务画面显示，补偿值=0.104mm



Service axis/spindle X1 1

	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	1.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	49.896	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	49.896	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.104	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

由上面三图可以看出，当MD32750=3H时，温度补偿值为一个不过零点的线性变化值。因此相关的参数有SD43900 $SA_TEMP_COMP_ABS_VALUE、SD43920 $SA_TEMP_COMP_REF_POSITION和SD43910 $SA_TEMP_COMP_SLOPE。

实验三：设置 MD32750=4H

T1 刀具类型 120，刀具长度 100mm，刀具半径 16mm

1. 三轴铣床（补偿后检查 Z 轴是否有补偿值）

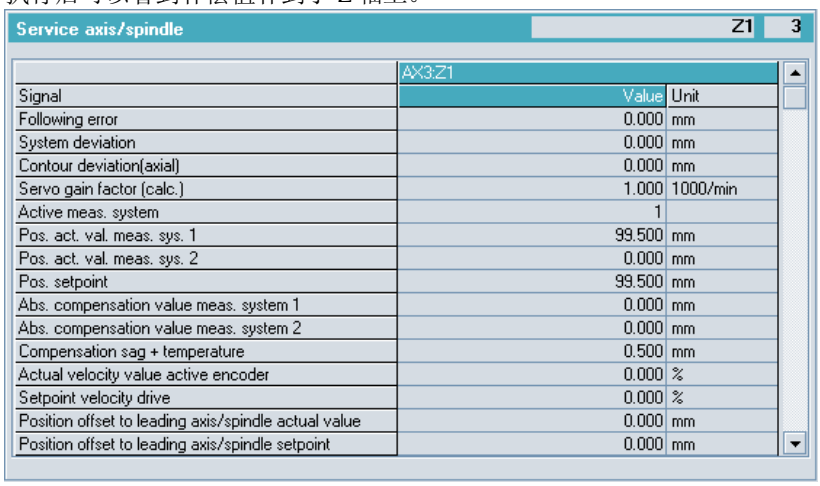
设置机床数据 MD20390 $MC_TOOL_TEMP_COMP_ON =1

设置设定数据 SD42960 TOOL_TEMP_COMP[2] = 0.5

执行下面程序：

```
T0M6
G0 X0 Y0 Z0
T1 M6
G1 Z0 F5000
M02
```

执行后可以看到补偿值补到了 Z 轴上。



2. 四轴铣床（Z 轴上带摆角轴--B 轴，补偿后检查 X 和 Z 轴是否有补偿值）

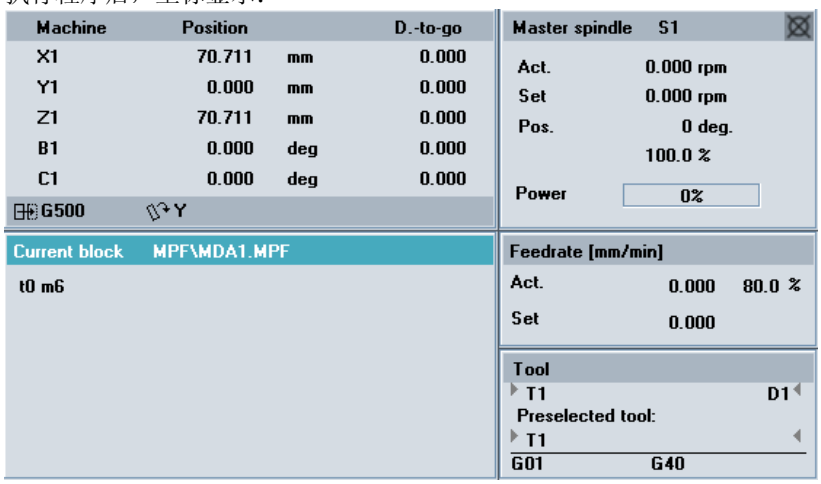
设置机床数据 MD20390 $MC_TOOL_TEMP_COMP_ON =1

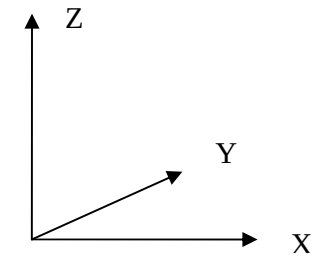
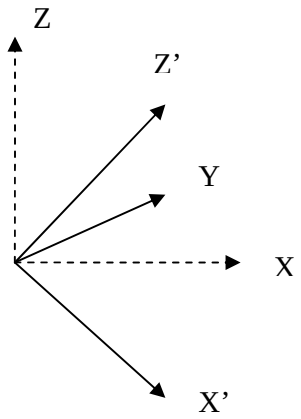
设置设定数据 SD42960 TOOL_TEMP_COMP[2] = 0.5

执行下面程序：

```
T0 M6
ROT Y0
G0 X0 Y0
G0 Z0 B0
$TC_CARR8[1]=1
ROT Y45
CUT2DF  TCOFR  TCARR=1 T1 D1
G1 Z0 F5000
M02
```

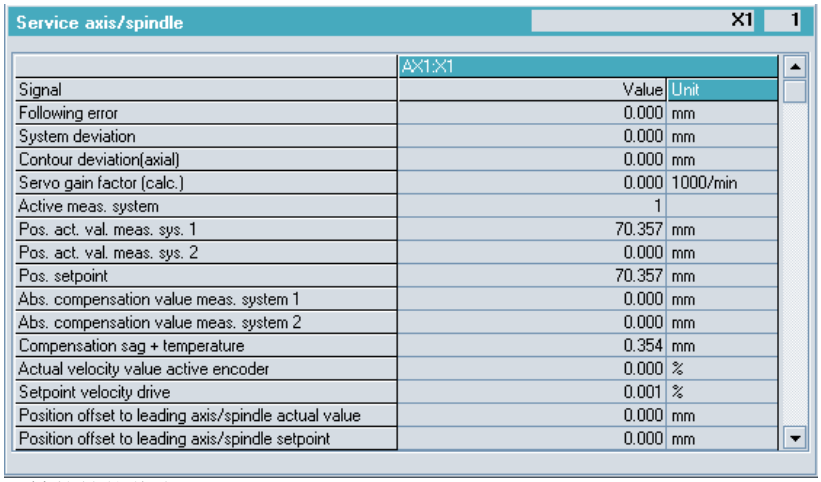
执行程序后，坐标显示：



旋转前坐标系	旋转后坐标系
	

执行程序后，查看诊断画面：

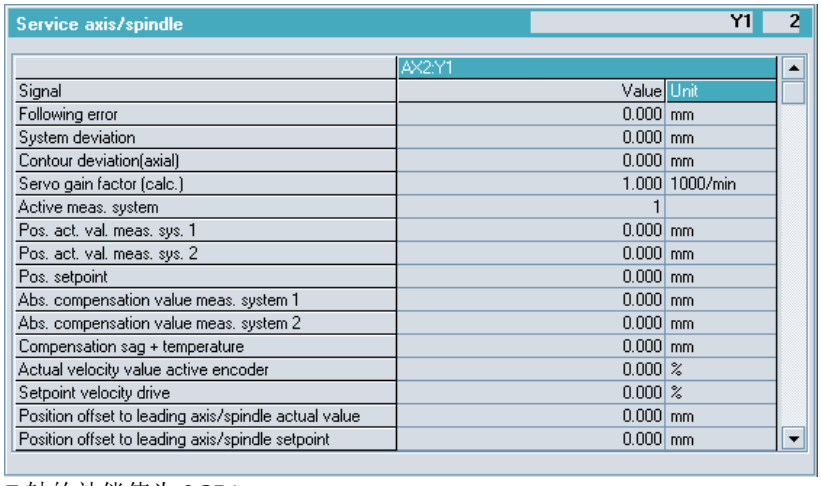
X 轴的补偿值为 0.354mm



Service axis/spindle X1 1

	AX1:X1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	0.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	70.357	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	70.357	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.354	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.001	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

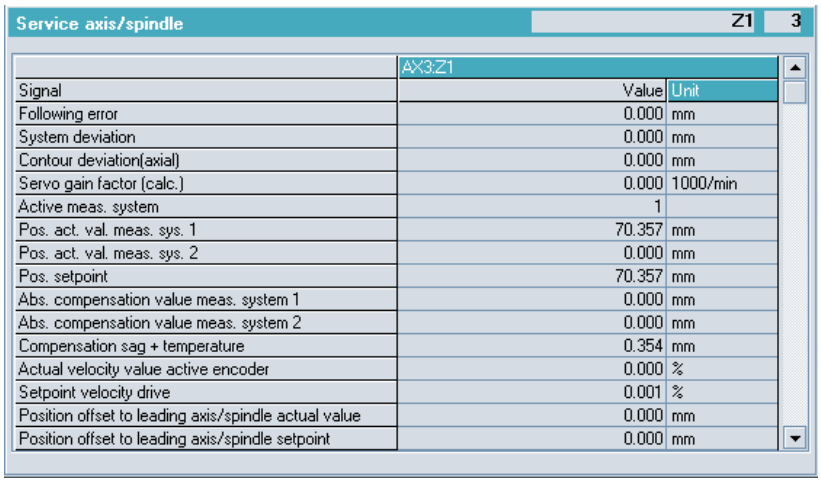
Y 轴的补偿值为 0mm



Service axis/spindle Y1 2

	AX2:Y1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	1.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	0.000	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	0.000	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.000	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.000	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

Z 轴的补偿值为 0.354mm



Service axis/spindle — Z1 — 3

	AX3:Z1	
Signal	Value	Unit
Following error	0.000	mm
System deviation	0.000	mm
Contour deviation(axial)	0.000	mm
Servo gain factor (calc.)	0.000	1000/min
Active meas. system	1	
Pos. act. val. meas. sys. 1	70.357	mm
Pos. act. val. meas. sys. 2	0.000	mm
Pos. setpoint	70.357	mm
Abs. compensation value meas. system 1	0.000	mm
Abs. compensation value meas. system 2	0.000	mm
Compensation sag + temperature	0.354	mm
Actual velocity value active encoder	0.000	%
Setpoint velocity drive	0.001	%
Position offset to leading axis/spindle actual value	0.000	mm
Position offset to leading axis/spindle setpoint	0.000	mm

沿刀长方向的补偿量为 0.5mm，分配到 X 和 Z 轴的补偿量为 0.5/1.414=0.354mm

补充：

1. MD20392 TOOL_TEMP_COMP_LIMIT[0]
   MD20392 TOOL_TEMP_COMP_LIMIT[1]
   MD20392 TOOL_TEMP_COMP_LIMIT[2]
   上面三个参数限制了三个几何轴在温度补偿时的补偿值。
   如果还是上面的例子，设置MD20392 TOOL_TEMP_COMP_LIMIT[2]=0.3，则X和Z轴的补偿值为0.3/1.414=0.212mm
2. SD42960 TOOL_TEMP_COMP[0]
   SD42960 TOOL_TEMP_COMP[1]
   SD42960 TOOL_TEMP_COMP[2]
   上面三个参数是在某温度下，在刀具方向上的补偿值。

作者：刘同