

## 4-Component Dynamometer (RCD)

Type 9170A...

### Rotating – for measuring cutting forces on a rotating tool

Rotating 4-component dynamometer for measuring the forces and torque on a rotating tool during cutting processes. Energy and measured values are transmitted on a non-contact basis, preventing wear.

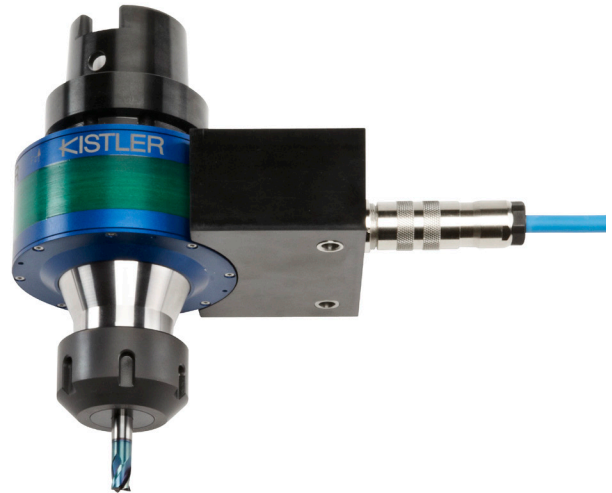
- Cutting force measurement on the rotating tool
- 4-component measurement:  $F_x$ ,  $F_y$ ,  $F_z$  and  $M_z$
- Up to max. 20 000 min<sup>-1</sup>
- Non-contact data transmission
- Internal cutting fluid supply possible
- Available for conventional machine spindle interfaces
- Tool holder with ER clamps
- High run-out and balance quality
- Complete measuring system

#### Description

The complete measuring system comprises a rotor, stator, connecting cable and signal conditioner. The spindle type on the machine tool determines which rotor version is required. The piezoelectric 4-component sensor, four charge amplifiers and the digital transmission electronics are integrated into the rotor. It measures the radial forces  $F_x$  and  $F_y$ , the axial force  $F_z$  and the torque  $M_z$ .

Digitized measuring signals to the stator, the range selection of the charge amplifiers and the power supply are transmitted contactless. The stator is fastened to the machine tool with a gap of a few millimeters.

The signal conditioner is responsible for the power supply, signal transmission and for controlling the system. Three measuring ranges can be selected and the measurement can be started either manually or via a serial interface. The measuring signal is an analog  $\pm 10$  Volt signal. Either the DynoWare software from Kistler, or compatible data acquisition software, can be used to record the data.



#### Applications

A rotating dynamometer is used to measure the three orthogonal forces  $F_x$ ,  $F_y$  and  $F_z$ , as well as the torque  $M_z$  during cutting production processes (milling and drilling, in particular). A rotating dynamometer enables the:

- Recording of the mechanical load during the cutting process
- Wear analysis
- Optimization of cutting parameters
- Calculation of material-specific constants (e.g. the specific cutting force)
- Optimization of tool geometry and coating
- Verification of cutting simulations

The forces and the torque are measured close to the cutting edge of the tool. This allows the active force vector on single-point tools to be measured directly. Due to the newly developed piezoelectric sensor located in the rotor, it is possible to record highly dynamic signals. The higher natural frequency and sampling rate, compared with the predecessor system, allows signals to be monitored during high-speed processes.

### Advantages of a rotating Dynamometer

Employing a rotating dynamometer as a measuring tool offers a number of advantages to the user. For example:

- The torque to be applied during the machining process is measured directly. This permits an accurate assessment of the condition of the tool, such as its state of wear
- The rotor of a rotating dynamometer rotates with the tool and allows the direct quantification of the mechanical load of the tool
- Thanks to the independence of workpiece mass, size and shape, the cutting force and torque can be measured on complex and cost-intensive components, e.g. structural parts of aircraft or Blisks (Blade Integrated Disc)

### Technical data

#### Rotor Type 9170Axxx0

Speed, max.		min <sup>-1</sup>	20 000 <sup>1)</sup>
Measuring range 1, nominal	$F_x, F_y$	N	-5 000 ... 5 000 <sup>2)</sup>
	$F_z$	N	-20 000 ... 20 000 <sup>2)</sup>
	$M_z$	N·m	-150 ... 150 <sup>2)</sup>
Measuring range 2, nominal	$F_x, F_y$	N	-2 000 ... 2 000 <sup>2)</sup>
	$F_z$	N	-5 000 ... 5 000 <sup>2)</sup>
	$M_z$	N·m	-50 ... 50 <sup>2)</sup>
Measuring range 3, nominal	$F_x, F_y$	N	-500 ... 500 <sup>2)</sup>
	$F_z$	N	-2 000 ... 2 000 <sup>2)</sup>
	$M_z$	N·m	-10 ... 10 <sup>2)</sup>
Sensitivity range 1	$F_x, F_y$	mV/N	≈2
	$F_z$	mV/N	≈0,5
	$M_z$	mV/N·m	≈66
Sensitivity range 2	$F_x, F_y$	mV/N	≈5
	$F_z$	mV/N	≈2
	$M_z$	mV/N·m	≈200
Sensitivity range 3	$F_x, F_y$	mV/N	≈20
	$F_z$	mV/N	≈5
	$M_z$	mV/N·m	≈1 000
Linearity		%FSO	≤±1,0
Hysteresis		%FSO	≤1,0

<sup>1)</sup> Rotors with spindle adapter DIN 69871-AD50, MAS 403 BT 50 or ANSI B5.50-50 are limited to 12 000 min<sup>-1</sup>.

<sup>2)</sup> Small spindle adapters limit the useable force range of the RCD. The rotors are calibrated in accordance with limit values (see page 4).

Crosstalk	$F_x \leftrightarrow F_y$	%FSO	≤±2,0
	$F_{x,y} \rightarrow F_z$	%FSO	≤±3,5
	$F_z \rightarrow F_{x,y}$	%FSO	≤±1,0
	$F_z \rightarrow M_z$	mN·m/N	≤±1
	$M_z \rightarrow F_z$	N/N·m	≤±1
Natural frequency <sup>2)</sup>	$f_{0, F_{x,y}}$	Hz	≈2 000
	$f_{0, F_z}$	Hz	≈7 600
Low-pass (anti-aliasing)		kHz	3,0
Low-pass filter Type			6 pol., Butterworth
Sampling rate per channel		kHz	22,2
Resolution		bit	12
Operating temperature range		°C	0 ... 60
Degree of protection (IEC 60529)			IP67
Internal cutting fluid pressure, max.		bar	70
Balancing class		G	≤2,5
Weight (rotor only) <sup>2)</sup>		kg	1,6

<sup>2)</sup> Applies to Type 9170A131 (RCD with HSK-A63 spindle adapter, ER clamp adapter, without tool)

#### Signal conditioner Type 5238Bx

Number of channels		4
Number of range per channel		3
Low-pass (adjustable)		
Cut-off frequency 1	kHz	0,3
Cut-off frequency 2	kHz	1,0
Cut-off frequency 3	kHz	3,0
Low-pass filter Type		6 pol., Butterworth
Signal output FSO	V	±10
Connector signal output		4xBNC neg. D-Sub neg. 15-pol.
Interface (for remote control)		RS-232C
Power supply	VAC	V
Tolerance	%	±10
Mains frequency	Hz	50 ... 60
Operating temperature range	°C	0 ... 60
Degree of protection (IEC 60529)		IP30
Dimensions	WxHxD	mm
Weight (signal conditioner only)	kg	3,4

### Signals of a rotating Dynamometer (RCD)

The Type 9170A... rotating dynamometer is based on a piezoelectric 4-component sensor. The rotor of the measuring system is connected to the machine spindle. This means that the coordinate system of the RCD also rotates around the vertical Z-axis. Due to the rotating coordinate system of the RCD, it is possible to directly assess the mechanical loads of the tool cutting edge.

Here are some examples of measurement signals acquired and displayed with the optional Kistler DynoWare Type 2825A software:

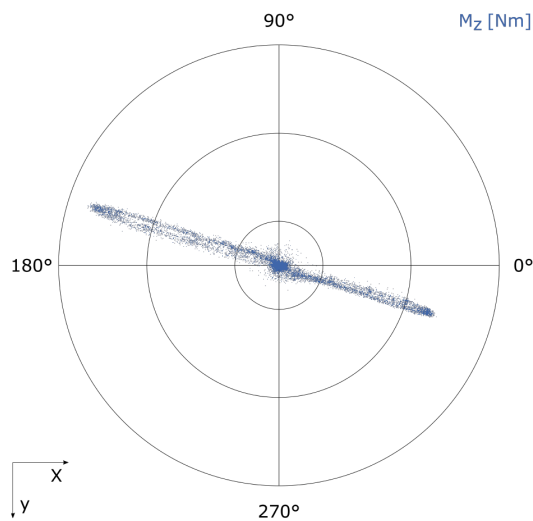


Fig. 1: Polarplot milling with double-edged tool for finishing

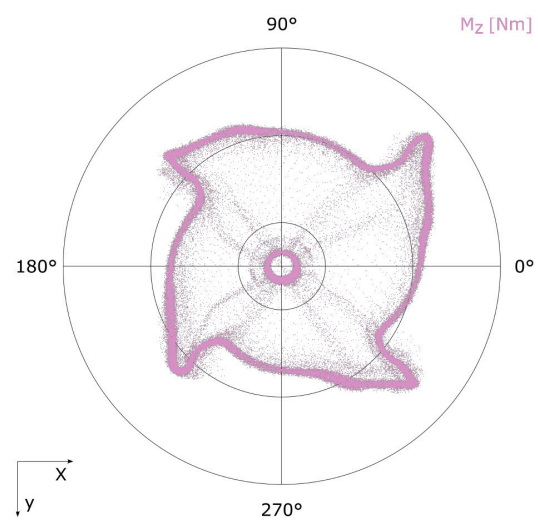


Fig. 2: Polarplot milling with four-edged tool in half section

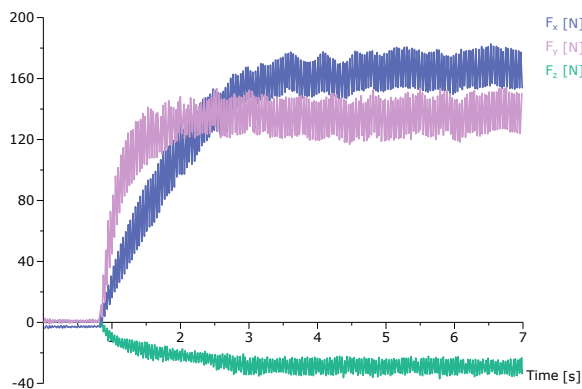


Fig. 3: Measurement data during milling

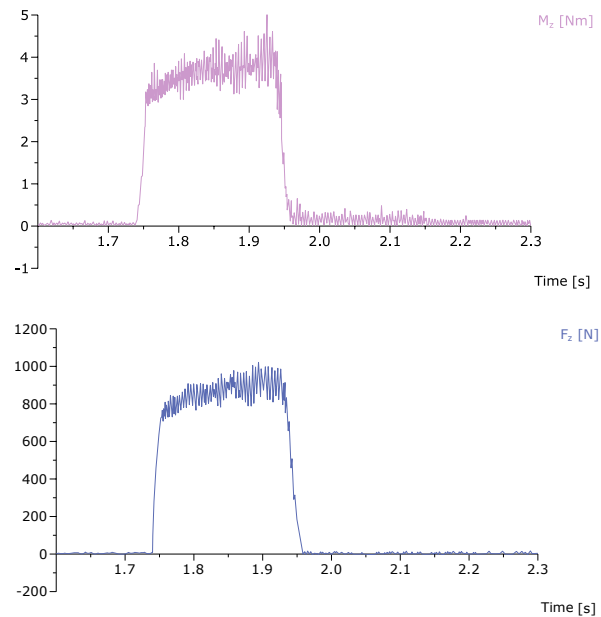


Fig. 4: Measurement data during drilling

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**Mounting the RCD Type 9170A...**

Like a conventional tool, the rotor of a rotating dynamometer is pulled into the machine spindle through the spindle adapter. Mounting the stator onto the machine structure or the stationary part of the machine spindle is up to the user. Reference the Type 9170A... instruction manual for more detailed information.

**Handling the RCD Type 9170A... during operation**

To prevent a collision between the stator and the stator holder, we recommend manually inserting the RCD Type 9170A... into the machine spindle.

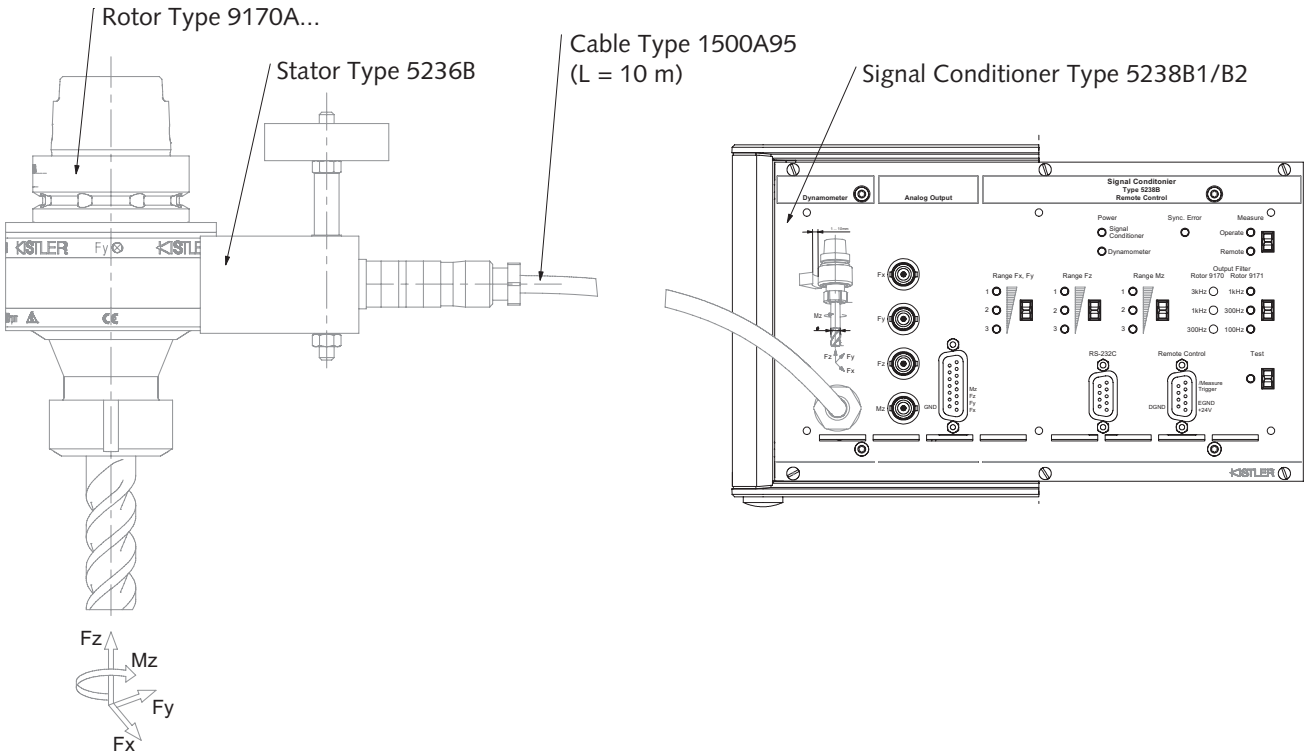


Fig. 5: Scheme of the measuring chain

**Typical measuring chain with DAQ system Type 5697A1**

Dynamometer (+ Stator)	Connection cable	Signal Conditioner	Connection cable	DAQ system	Notebook (from customer side) with DynoWare
Type 9170A (+ Typ 5236B)	Type 1500A95	Type 5238B	Type 1700A111A2 Type 1200A27	Type 5697A1	

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### Calibration ranges of the different RCD Types

Type	Machine adapter			Calibration range 1	Calibration range 2	Calibration range 3
9170A111x	HSK-A40	$F_x, F_y$	N	1 000	500	250
		$F_z$	N	12 000	4 500	1 800
		$M_z$	N·m	80	45	9
9170A121x	HSK-A50	$F_x, F_y$	N	1 500	1 000	250
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A131x	HSK-A63	$F_x, F_y$	N	3 000	1 500	300
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A141x	HSK-A80	$F_x, F_y$	N	4 500	1 800	450
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A161x	HSK-E40	$F_x, F_y$	N	1 000	500	250
		$F_z$	N	12 000	4 500	1 800
		$M_z$	N·m	15	12	9
9170A171x	HSK-E50	$F_x, F_y$	N	1 500	1 000	250
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	35	25	9
9170A181x	HSK-E63	$F_x, F_y$	N	3 000	1 500	300
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	70	45	9
9170A211x	DIN ISO 7388-1 - AD30 (DIN 69871-AD30)	$F_x, F_y$	N	1 000	500	250
		$F_z$	N	12 000	4 500	1 800
		$M_z$	N·m	80	45	9
9170A221x	DIN ISO 7388-1 - AD40 (DIN 69871-AD40)	$F_x, F_y$	N	3 000	1 500	300
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A231x	DIN ISO 7388-1 - AD50 (DIN 69871-AD50)	$F_x, F_y$	N	4 500	1 800	450
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A241x	JIS B 6339-2 JD 30 (MAS 403 BT 30)	$F_x, F_y$	N	1 000	500	250
		$F_z$	N	12 000	4 500	1 800
		$M_z$	N·m	80	45	9
9170A251x	JIS B 6339-2 JD 40 (MAS 403 BT 40)	$F_x, F_y$	N	3 000	1 500	300
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A261x	JIS B 6339-2 JD 50 (MAS 403 BT 50)	$F_x, F_y$	N	4 500	1 800	450
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A271x	ANSI / ASME B5.50-30 (CAT 30)	$F_x, F_y$	N	1 000	500	250
		$F_z$	N	12 000	4 500	1 800
		$M_z$	N·m	80	45	9
9170A281x	ANSI / ASME B5.50-40 (CAT 40)	$F_x, F_y$	N	3 000	1 500	300
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A291x	ANSI / ASME B5.50-50 (CAT 50)	$F_x, F_y$	N	4 500	1 800	450
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A311x	Capto C5	$F_x, F_y$	N	1 500	1 000	250
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9
9170A321x	Capto C6	$F_x, F_y$	N	3 000	1 500	300
		$F_z$	N	18 000	4 500	1 800
		$M_z$	N·m	100	45	9

### Ordering example: 9170A1312

Tested RCD Type 9170A... measuring system consisting of:

- Integrated spindle adapter HSK-A63
- Integrated collet holder ER, size 32 (DIN 6499-B32)
- Stator
- Connecting cable
- Signal conditioner in desktop case

The individual system components can also be ordered separately:

#### Component

- Rotor
- Stator
- Connecting cable (l = 10 m)
- Signal conditioner for rack installation
- Signal conditioner for desktop case
- Clamping wrench for ER collets

#### Type

9170Axx10  
5236B  
1500A95  
5238B1  
5238B2  
65007932

### Ordering key

Collets DIN 6499-B32-UP

#### Diameter d of tool

1 ... 2 mm	02
2 ... 3 mm	03
3 ... 4 mm	04
4 ... 5 mm	05
5 ... 6 mm	06
6 ... 7 mm	07
7 ... 8 mm	08
8 ... 9 mm	09
9 ... 10 mm	10
10 ... 11 mm	11
11 ... 12 mm	12
12 ... 13 mm	13
13 ... 14 mm	14
14 ... 15 mm	15
15 ... 16 mm	16
16 ... 17 mm	17
17 ... 18 mm	18
18 ... 19 mm	19
19 ... 20 mm	20

Type 9169A ☐

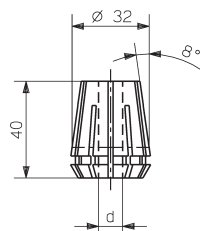


Fig. 2: Collet Type 9169A...

### Included accessories

- Clamping wrench for ER collets
- Clamping nut Hi-Q/ER32 for ER collet

### Type/Art. No.

65007932  
65007915

### Optional accessories

- Collets DIN 6499-B32-UP

### Ordering key

Rotating 4-Component Dynamometer  
(RCD) for Cutting Force  
Measurement

Type 9170A ☐ ☐ ☐

#### Spindle adapter (integrated)

HSK-A40	11
HSK-A50	12
HSK-A63	13
HSK-A80	14
HSK-E40	16
HSK-E50	17
HSK-E63	18
DIN ISO 7388-1 - AD30 (DIN 69871-AD30)	21
DIN ISO 7388-1 - AD40 (DIN 69871-AD40)	22
DIN ISO 7388-1 - AD50 (DIN 69871-AD50)	23
JIS B 6339-2 JD 30 (MAS 403 BT 30)	24
JIS B 6339-2 JD 40 (MAS 403 BT 40)	25
JIS B 6339-2 JD 50 (MAS 403 BT 50)	26
ANSI / ASME B5.50-30 (CAT 30)	27
ANSI / ASME B5.50-40 (CAT 40)	28
ANSI / ASME B5.50-50 (CAT 50)	29
Capto C5	31
Capto C6	32

Other spindle adapters available on request

#### Tool holder (integrated)

Collet holder ER (DIN 6499 – B32)	1
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#### Measuring system

Rotor only	0
Complete measuring system with rotor, stator, connecting cable and signal conditioner (rack mounted unit)	1
Complete measuring system with rotor, stator, connecting cable and signal conditioner (desktop case)	2

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