

4-component Dynamometer (RCD)

Type 9171A...

Rotating – for measuring cutting forces in heavy machining

The rotating 4-component dynamometer (RCD) Type 9171A... permits the measurement of the forces and the on a rotating tool. It is mounted in the machine spindle instead of a common tool holder. 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 as well as M_z
- up to max. 12 000 min^{-1}
- Forces measurable up to 30 kN
- Non-contact data transmission
- Internal cutting fluid supply possible
- Available for conventional machine spindle interfaces
- Several tool adapters available
- High run-out accuracy and balancing 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 spindle adapter is also exchangeable. The same applies to the tool adapters. 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 , axial force F_z as well as torque M_z .

Digitized measuring signals to the stator, the range selection of the charge amplifiers and the power supply are transmitted without contact. The stator is fastened to the machine tool with a gap of a few millimeters.

The signal conditioner is the interface to the following data acquisition system. It is responsible for the power supply and the control of the system. Settings of measuring ranges as well as settings at the low-pass filter are performed manually at the signal conditioner or via the serial interface. The measuring signals are available as analog ± 10 Volt signal. Either the DynoWare software from Kistler, or compatible data acquisition software, can be used to record the data.

Application

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

- Recording of the mechanical load during the cutting process
- Analysis of the wear process
- 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 flute tools to be measured directly. Due to the newly developed piezoelectric sensor located in the rotor, it is possible to record highly dynamic signals.

Advantages of a rotating Dynamometer

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

- 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 of the cutting process can be measured on complex and cost-intensive components, e.g. structural parts of aircraft or Blisks (Blade Integrated Disc)

Technical data

Rotor Type 9171Axxx0

Speed, max.	min ⁻¹	12 000
Measuring range 1, nominal	F_x, F_y	N
	F_z	N
	M_z	N·m
Calibration range		in acc. with page 6
Sensitivity range 1	F_x, F_y	mV/N
	F_z	mV/N
	M_z	mV/N·m
Sensitivity range 2	F_x, F_y	mV/N
	F_z	mV/N
	M_z	mV/N·m
Sensitivity range 3	F_x, F_y	mV/N
	F_z	mV/N
	M_z	mV/N·m
Linearity	%FSO	≤±1,0
Hysteresis	%FSO	≤1,0
Crosstalk	$F_x \leftrightarrow F_y$	%FSO
	$F_{x,y} \rightarrow F_z$	%FSO
	$F_z \rightarrow F_{x,y}$	%FSO
	$F_z \rightarrow M_z$	mN·m/N
	$M_z \rightarrow F_z$	N/N·m
Natural frequency ¹⁾	$f_0, F_{x,y}$	Hz
	f_0, F_z	Hz
Natural frequency ²⁾	$f_0, F_{x,y}$	Hz
	f_0, F_z	Hz
Low-pass (anti-aliasing)	kHz	3,0
Low-pass filter type		6 pole, 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, without spindle adapter, without tool adapter)	kg	≈3,3
Weight Type 9171A151x (with attached spindle adapter HSK-A100 and tool adapter ER32) measured without tool and clamping nut	kg	≈7,2

¹⁾ Applies to Type 9171A150x (RCD with spindle adapter HSK-A100, without tool adapter)

²⁾ Applies to Type 9171A151x (RCD with spindle adapter HSK-A100 and tool adapter ER32) measured with collet, clamping nut, tool $m_{\text{tool}} = 126 \text{ g}$

Signal conditioner Type 5238B...

Number of channels		4
Number of ranges per channel		3
Low-pass (adjustable)		
Cut-off frequency 1	kHz	0,1
Cut-off frequency 2	kHz	0,3
Cut-off frequency 3	kHz	1,0
Low-pass filter type		6 pole, Butterworth
Signal output FSO	V	±10
Connector signal output		4xBNC neg. D-Sub neg. 15 pin
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	248x253x146
Weight (signal conditioner only)	kg	3,4

Signals of a rotating Dynamometer (RCD)

The Type 9171A... rotating dynamometer is based on a piezo-electric 4-component sensor and it represents the core element of the rotor design. Through the spindle interface, the rotor is installed directly by the machine spindle and therefore follows the rotation. 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:

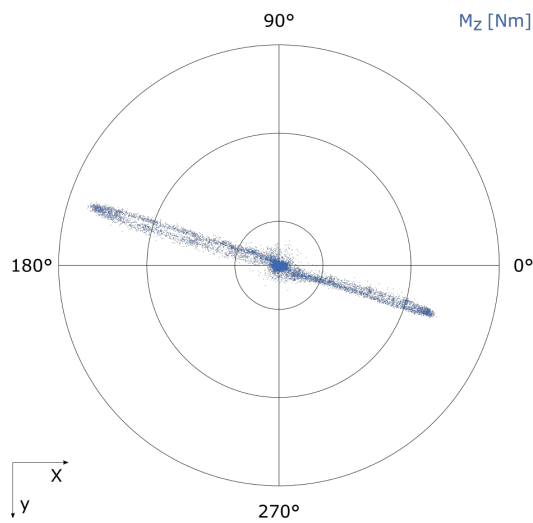


Fig. 1: Polarplot milling with double-edged tool for finishing

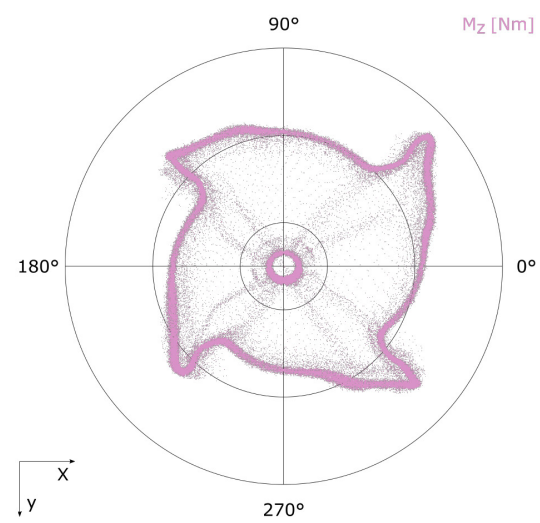


Fig. 2: Polarplot milling with four-edged tool in half section

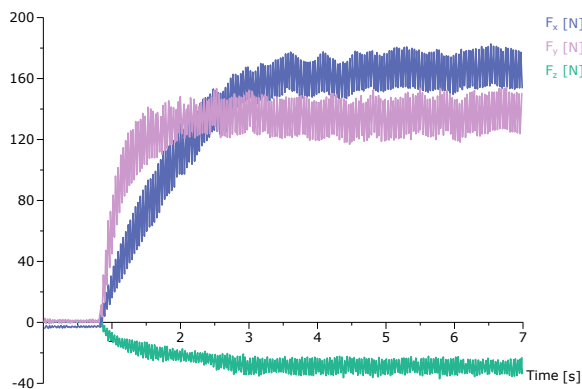


Fig. 3: Measurement data during milling

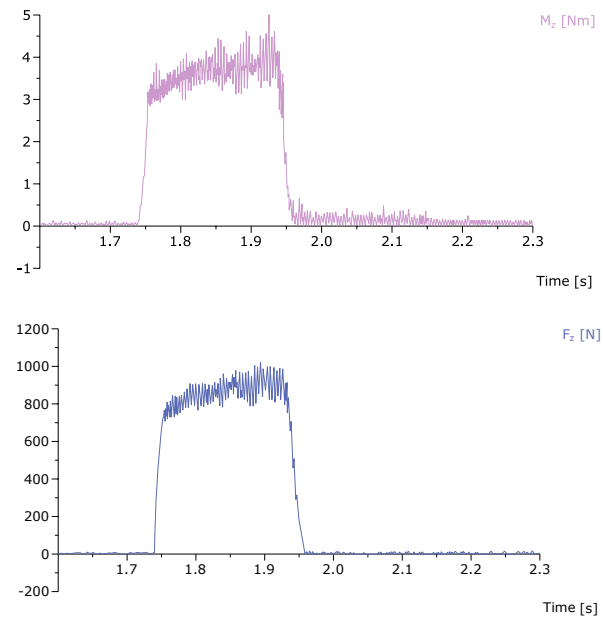


Fig. 4: Measurement data during drilling

9171A_003-155d-08.19

Modularity

The spindle adapter as well as the tool adapter for Type 9171A... are removable to provide the highest possible flexibility to the user. For example, by simply exchanging the spindle adapter it is possible to use the dynamometer on several machine tools with different spindle interfaces. The detailed description of the process can be found in the instruction manual.

Mounting the RCD Type 9171A...

Like a conventional tool, the rotor of a rotating dynamometer is pulled into the machine spindle through the spindle adapter. The user is responsible for mounting the stator onto the machine structure or the stationary part of the machine spindle. There is a detailed description of this procedure in the instruction manual.

Handling the RCD Type 9171A... during operation

To prevent a collision between the stator and the stator holder, we recommend inserting the RCD Type 9171A... into the machine spindle manually.

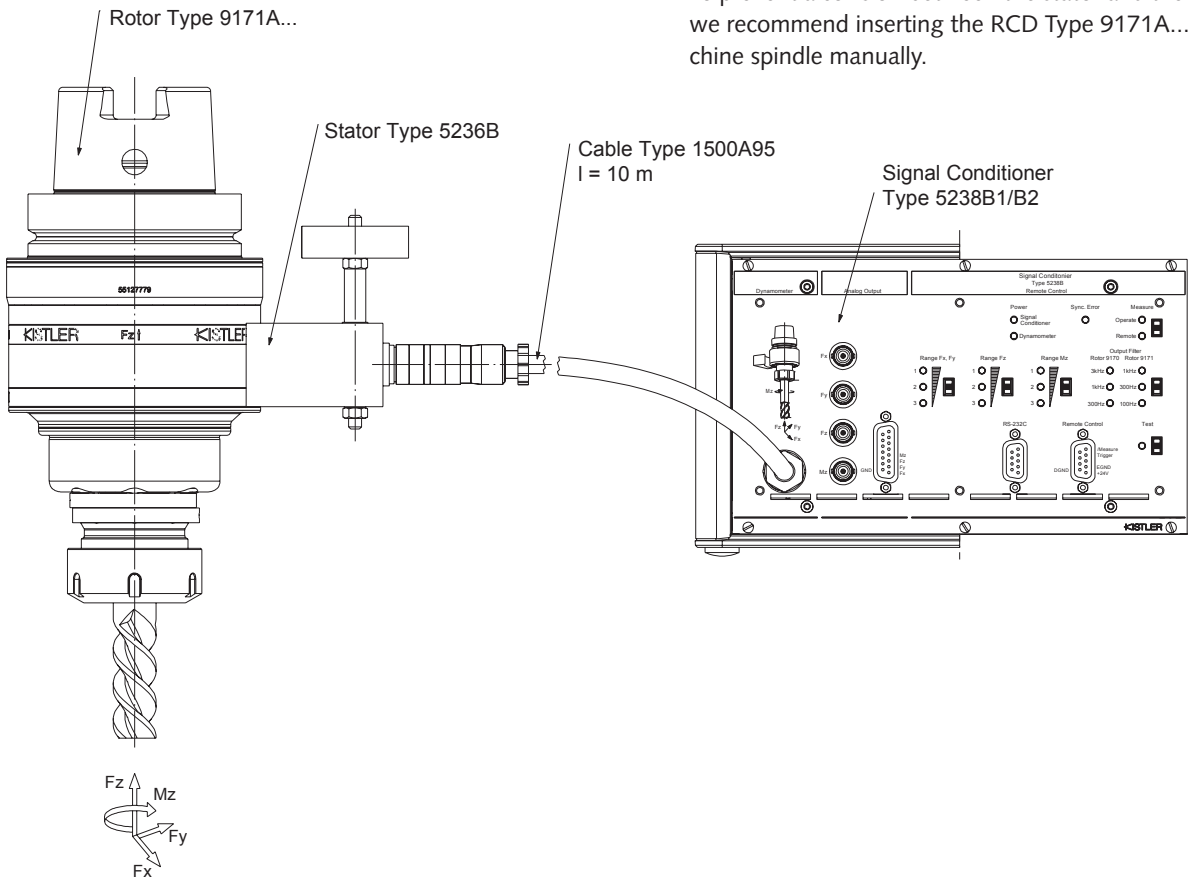


Fig. 5: Scheme of the measuring chain

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 9171A (+ Type 5236B)	Type 1500A95	Type 5238B	Type 1700A111A2 Type 1200A27	Type 5697A1	

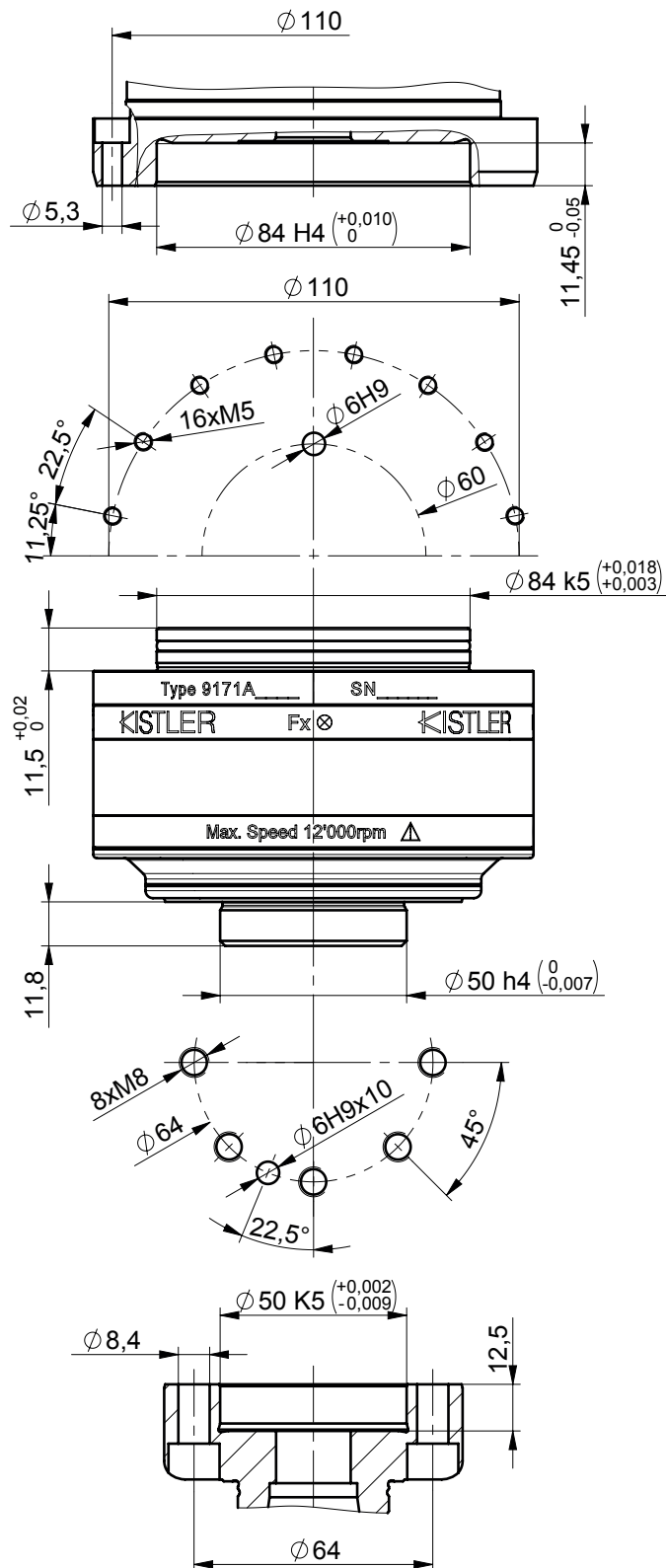


Fig. 2: Dimensions of interfaces

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Calibration ranges of the different RCD Types

Type	Spindle Adapter			Calibration range 1	Calibration range 2	Calibration range 3
9171A100x	–	F _x , F _y	N	18 000	7 500	1 900
		F _z	N	28 000	7 500	1 900
		M _z	N·m	1 000	380	95
9171A13xx	HSK-A63	F _x , F _y	N	3 000	1 500	300
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A14xx	HSK-A80	F _x , F _y	N	5 000	2 500	500
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A15xx	HSK-A100	F _x , F _y	N	7 500	4 000	1 000
		F _z	N	28 000	7 000	1,500
		M _z	N·m	1 000	380	95
9171A22xx	DIN ISO 7388-1 - AD40 (DIN 69871-AD40)	F _x , F _y	N	3 000	1 500	300
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A23xx	DIN ISO 7388-1 - AD50 (DIN 69871-AD50)	F _x , F _y	N	7 000	3 500	500
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A25xx	JIS B 6339-2 JD 40 (MAS 403 BT 40)	F _x , F _y	N	3 000	1 500	300
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A26xx	JIS B 6339-2 JD 50 (MAS 403 BT 50)	F _x , F _y	N	7 000	3 500	500
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A28xx	ANSI / ASME B5.50-40 (CAT 40)	F _x , F _y	N	3 000	1 500	300
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A29xx	ANSI / ASME B5.50-50 (CAT 50)	F _x , F _y	N	7 000	3 500	500
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A32xx	Capto C6 *	F _x , F _y	N	3 000	1 500	300
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95
9171A33xx	Capto C8 *	F _x , F _y	N	5 000	2 500	500
		F _z	N	28 000	7 000	1 500
		M _z	N·m	1 000	380	95

* Not possible to use together with center bolt clamping

Components of a measuring chain

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

Type

9171Axxx0
5236B
1500A95
5238B1
5238B2

Ordering example: 9171A3232

Tested RCD Type 9171A... measuring system consisting of:

- Rotor Type 9171A100
- Mounted spindle adapter Capto C6 (removable)
- Mounted powRgrip collet chuck secuRgrip PG32-SG (removable)
- Stator Type 5236B
- Connection cable Type 1500A95
- Signal conditioner Type 5238B2

Ordering key

Rotating 4-component
Cutting force dynamometer RCD

Type 9171A

Spindle adapter (removable)

Flange adapter (w/o spindle adapter)	10
HSK-A63	13
HSK-A80	14
HSK-A100	15
DIN ISO 7388-1 - AD40 (DIN 69871-AD40)	22
DIN ISO 7388-1 - AD50 (DIN 69871-AD50)	23
JIS B 6339-2 JD 40 (MAS 403 BT 40)	25
JIS B 6339-2 JD 50 (MAS 403 BT 50)	26
ANSI / ASME B5.50-40 (CAT 40)	28
ANSI / ASME B5.50-50 (CAT 50)	29
Capto C6	32
Capto C8	33

Additional spindle adapters on request

Tool adapter (removable)

Flange adapter (w/o tool adapter)	0
Collet chuck ER 32 (DIN 6499 – B32)	1
Collet chuck ER 40 (DIN 6499 – B40)	2
powRgrip collet chuck secuRgrip PG 32-SG	3
TENDO hydraulic expansion chuck	4
MEGA collet chuck 20N, New Baby Chuck	5

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

Spindle adapter (available separately)

Spindle Adapter	Art. No.
HSK-A63	55127703
HSK-A80	55127778
HSK-A100	55127779
DIN ISO 7388-1 - AD40 (DIN 69871-AD40)	55127805
DIN ISO 7388-1 - AD50 (DIN 69871-AD50)	55127806
JIS B 6339-2 JD 40 (MAS 403 BT 40)	55127808
JIS B 6339-2 JD 50 (MAS 403 BT 50)	55127809
ANSI / ASME B5.50-40 (CAT 40)	55127812
ANSI / ASME B5.50-50 (CAT 50)	55127817
Capto C6 *	55127820
Capto C8 *	55127821

* Not possible to use together with center bolt clamping

Included accessories

- Coolant tube
- O-ring seal for coolant tube
- Balancing ring
- Screws
- Stop bolt

Tool adapter (available separately)

Tool Adapter	Art. No.
Collet chuck ER32 (DIN 6499-B32)	55127219
Collet chuck ER40 (DIN 6499-B40)	55127224
powRgrip collet chuck secuRgrip PG32-SG	55125318
TENDO hydraulic expansion chuck	55171559
MEGA collet chuck 20N, New Baby Chuck	55187242

Included accessories for tool adapter

- Clamping nut
- Hook wrench (only ER collet chuck)
- Ratchet spanner/handle bar (only powRgrip collet chuck secuRgrip)
- Balancing rings
- Screws
- Stop bolts

Ordering key

Collet DIN 6499-B32-UP

Type 9169A ☐

Tool Diameter d

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

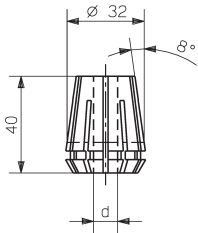


Fig. 2: Collet Type 9169A...

TENDO is a registered trademark of Schunk GmbH.

MEGA New Baby Chuck is a registered trademark of BIG Daishowa Group.

Capto is a registered trademark of the Sandvik Group.

powRgrip and secuRgrip are registered trademarks of Rego-Fix AG.

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