Document version: BN 405-001e b

1 Purpose

This standard regulates the procedure for balancing couplings and comparable components. Individual parts as well as bolted-together assemblies are balanced, depending on how the order specifies it. In case of ambiguities or contradictions, DELLNER BUBENZER Germany GmbH (hereinafter referred to as "DBG") must be consulted.

2 Applicable documents

DIN ISO 21940-11   Mechanical vibration - Rotor balancing - Part 11: Procedures and tolerances for rotors with rigid behaviour

DIN ISO 21940-32   Mechanical vibration - Rotor balancing - Part 32: Shaft and fitment key convention

BN 405-009   Marking of coupling parts

3 Order specification

The purchase order contains the balancing grade according to DIN ISO 21940-11 for the component to be balanced as well as the maximum operating speed. Furthermore, the order specifies whether an individual part balancing, a test balancing of the assembly or an assembly balancing with correction is to be performed. If balancing protocols are required, this is also listed in the order specification. If protocols are created, it must be possible to assign them unambiguously to the individual part or the assembly. For this purpose, the identification markings on the components must be listed in the report. The balancing protocols must be sent as a PDF to zeugnisse.de@dellnerbubenzer.com on the day of delivery at the latest.

4 Balancing procedures

The balancing procedures describe the procedure for single part and assembly balancing. In the assembled state, the form and position properties of the interfaces (mostly centering fits) determine the resulting balancing quality. For this reason, poor quality must always be assumed for an assembly, which can only be eliminated by lower manufacturing tolerances, better individual part balancing qualities or a correction in the assembled state. A correction in the assembly always requires the complete assembly to be replaced if individual parts are to be replaced in order to restore the balance quality of the assembly.

4.1 Single-part balancing

The individual parts in the order are balanced according to the specified balancing grade, the maximum operating speed and the following boundary conditions for auxiliary equipment and keyways. The reference axis for balancing is determined by the component interface (in the case of a flange or hub, it is usually the main bore). Only the weight of the component to be balanced is used to determine the permissible residual unbalance. Fixtures must qualitatively correspond to the required balancing grade and should be as light as possible.

4.2 Assembly test balancing

The individual parts of an assembly are first balanced individually according to section 4.1. The components are then assembled as specified for field installation (see drawing or order text) and subjected to test balancing to the specified quality without balancing correction.

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If the required balancing quality is not achieved, the individual parts must be rebalanced. If not excluded by drawing or order specification, the angular position of the individual part residual unbalances can be adjusted to achieve better results in the assembly.

After successful test balancing, the position of the components relative to each other must be captively marked in accordance with BN 405-009.

4.3 Assembly balancing with correction

In the case of assembly balancing with correction, balancing of one of the assembled parts can be dispensed with. All other components are balanced according to section 4.1. The balancing correction in the assembly is then performed on the unbalanced component. For example, in the case of a hub-claw ring assembly, it is advisable to balance the hub first and then to make the correction on the claw ring in the assembled hub-claw ring assembly.

After successful balancing, the position of the components in relation to each other must be captively marked in accordance with BN 405-009.

5 Dynamic and static balancing process

A dynamic balancing procedure takes place under rotation and requires at least two measuring or balancing planes. This method is usually used for rod-shaped rotors (coupling parts).

The static balancing method requires only one measuring or correction plane and is suitable for disc-shaped rotors such as brake discs. With only one measuring plane, moment imbalances cannot be determined, so that rotation is not absolutely necessary in the balancing procedure. This means that, for example, brake discs and similar components can be tested with a balancing scale. In principle, the same conditions apply to the use of a balancing scale as to a rotating balancing machine.

The characteristic feature of a disc-shaped rotor is that the component outside diameter is greater than the component length.

6 Conditions for the balancing process

The balancing process brings the center of mass/axis into overlap with the component axis of rotation in order to minimize rotating centrifugal forces. Therefore, the immediate component interface, such as the main bore of a hub, serves as the reference axis for the balancing process. This means that all positional tolerances and permissible residual unbalances refer to this axis of rotation. Appendix A of this document contains illustrations of common coupling parts with the reference axes for the balancing process.

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6.1 Tolerances for auxiliary equipment

If auxiliary equipment or auxiliary surfaces are required for the balancing process, it must be ensured that the geometric deviation from the reference axis is within the permissible tolerance.
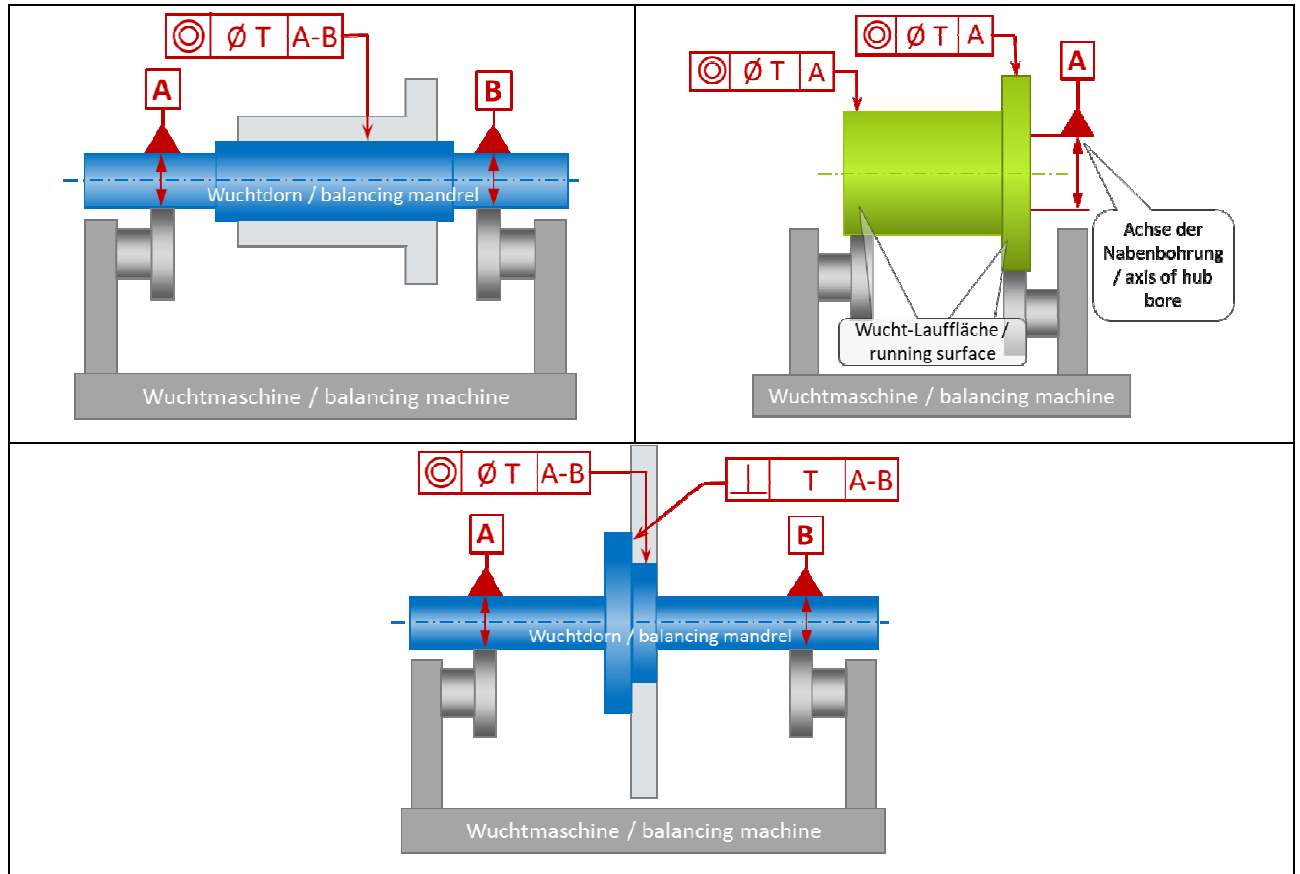

Fig. 6.1: Auxiliary equipment and auxiliary surfaces

The requirements for the fixture and the auxiliary surfaces on the component itself are based on the required balancing quality. It must be ensured that the unbalance caused by the deviations on the auxiliary equipment is smaller than the required balancing quality of the component.

Sign/Formula	Unit	Description
$T \leq \dfrac{20}{\sqrt{2}} \cdot \dfrac{G}{n_{max}}$	mm	Permissible average tolerance (coaxiality) of the auxiliary
with		
G	mm/s	Balancing grade acc. to DIN ISO 21940-11
n_{max}	1/min	Maximum operating speed
$T := \dfrac{20}{\sqrt{2}} \cdot \dfrac{6,3}{1900} = 0,047$	mm	Example: G 6,3; n_{max}=1,900 1/min → Coaxiality condition Ø 0.047 mm

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In addition to the coaxiality of the centering on the balancing device, the fit clearance to the component also plays an important role. If clearance cannot be avoided for mounting reasons, the sum of clearance and coaxiality error should not exceed value *T*.

If the fixture does not offer centering, component centering alignment within value *T* is also permissible. An alternative surface can also be used for alignment if the manufacturing process ensures the coaxiality of the substitute surface to the component centering.

If bolts or other fasteners are required to hold the component in place for balancing, ensure that they are of equal weight and are applied on the same radius with the same angular pitch. The difference in weight of the fasteners in one plane must not exceed 0.1 gram or 0.05% of the weight of a fastener (whichever is greater).

6.2 Parallel key agreement

Unless otherwise specified in the order, the component is balanced with an inserted half key according to DIN ISO 21940-32. As an alternative to the physical half key, a calculated compensation via the balancing machine is also permissible. It is assumed that the hub keyway is filled with the half parallel key over the complete seat length. In the case of a shaft, the groove must be completely filled with half the parallel key so that the desired balancing condition can be produced in the assembled state. The following table shows the geometrical data and masses (steel) for the corresponding shaft diameters and parallel keyways according to DIN 6885. When determining the angular position, the center of the keyway must be taken into account.

Wellen-durchmesser d über/bis [mm]	Passfeder DIN 6885 b [mm]		h [mm]	Nut DIN 6885 t1 [mm]	t2 [mm]	Komplette Passfeder Form A [g/mm]	Gewicht Passfederanteil in der Welle [g/mm]	Schwerpunkt-radius [mm]		Gewicht Passfederanteil in der Nabe [g/mm]	Schwerpunkt-radius [mm]	
38 / 44	12	x	8	5	3,3	0,754	0,443	$d/2$	-2,64	0,311	$d/2$	+1,34
44 / 50	14	x	9	5,5	3,8	0,989	0,566	$d/2$	-2,67	0,423	$d/2$	+1,81
50 / 58	16	x	10	6	4,3	1,256	0,704	$d/2$	-2,94	0,553	$d/2$	+2,04
58 / 65	18	x	11	7	4,4	1,554	0,927	$d/2$	-3,46	0,628	$d/2$	+2,01
65 / 75	20	x	12	7,5	4,9	1,884	1,102	$d/2$	-3,73	0,782	$d/2$	+2,24
75 / 85	22	x	14	9	5,4	2,418	1,467	$d/2$	-4,49	0,951	$d/2$	+2,48
85 / 95	25	x	14	9	5,4	2,748	1,652	$d/2$	-4,53	1,096	$d/2$	+2,44
95 / 110	28	x	16	10	6,4	3,517	2,056	$d/2$	-5,05	1,461	$d/2$	+2,91
110 / 130	32	x	18	11	7,4	4,522	2,583	$d/2$	-5,59	1,940	$d/2$	+3,37
130 / 150	36	x	20	12	8,4	5,652	3,170	$d/2$	-6,37	2,482	$d/2$	+3,58
150 / 170	40	x	22	13	9,4	6,908	3,818	$d/2$	-6,65	3,090	$d/2$	+4,30
170 / 200	45	x	25	15	10,4	8,831	4,972	$d/2$	-7,69	3,859	$d/2$	+4,76
200 / 230	50	x	28	17	11,4	10,99	6,288	$d/2$	-8,72	4,702	$d/2$	+5,23
230 / 260	56	x	32	20	12,4	14,067	8,319	$d/2$	-10,26	5,749	$d/2$	+5,68

Table 6.2: Mass (steel) and geometry values to compensate for the half key

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Example for the determination of the key compensation
Shaft d = 135 mm; parallel key 36x20; seat length 150 mm; material: steel
Compensation mass for the half key in the hub: $\qquad 2,482 \ \frac{g}{mm} \cdot 150 \ mm = 372,3 \ g$
Radius from the axis of rotation to the center of gravity of the compensation mass: $\qquad \dfrac{135 \ mm}{2} + 3,58 \ mm = 71,08 \ mm$

As an alternative to the balancing process with previously inserted keyway and a calculated compensation of the half key, balancing can also be carried out before inserting the keyway. With this procedure, the head clearance between the key and the ground of the keyway in the hub is neglected in the assembled state.

If a pressure screw is provided in the hub/flange for fixing the parallel key, it must be screwed in before the balancing process so that it is flush with the ground of the keyway. The original pressure screw or one of the same weight must be used.
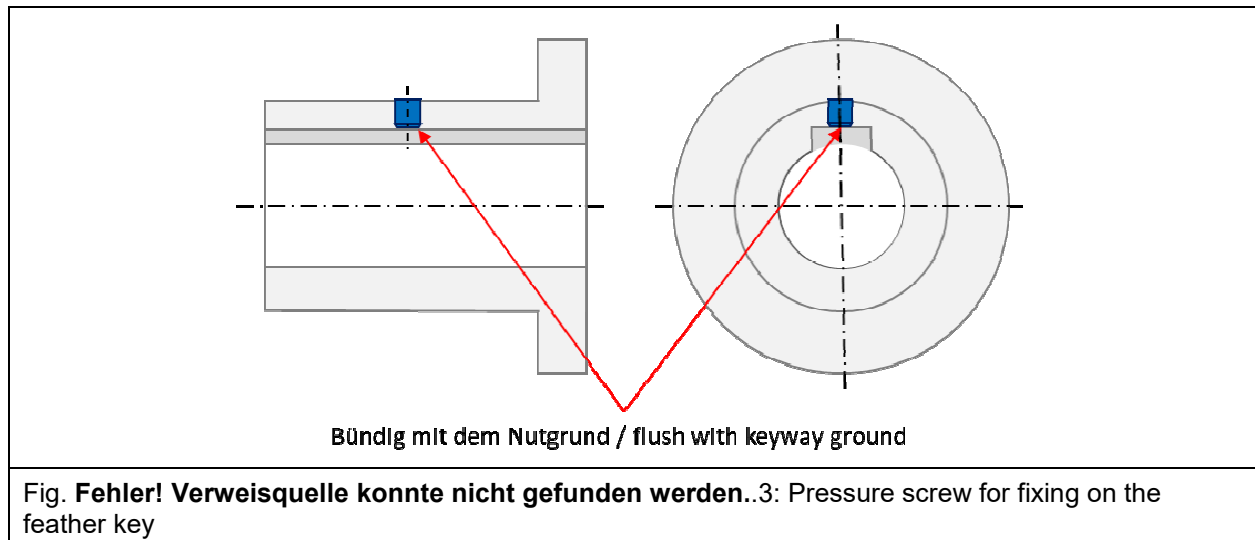

Bündig mit dem Nutgrund / flush with keyway ground

Fig. **Fehler! Verweisquelle konnte nicht gefunden werden.**.3: Pressure screw for fixing on the feather key

The neglect of the parallel key head clearance should be checked at high operating speeds and/or high demands on the balancing quality. In the following table, the unbalance due to the head clearance can be extrapolated to the keyway length and compared with the permissible balancing tolerance. The unbalance due to head clearance should not exceed 50 % of the permissible component unbalance.

Sign/formular	Unit	Description
$U_{K,per} \leq 5000 \cdot \dfrac{G}{n_{max}} \cdot m_R$	g mm	Permissible unbalance from neglecting the key head clearance in the assembled state
with		
G	mm/s	Balancing grade acc. to DIN ISO 21940-11
n_{max}	1/min	Maximum operating speed
m_R	kg	Mass of the rotor (mounted coupling assembly)

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$U_{K,per} := 5000 \cdot \dfrac{2,5}{6000} \cdot 30,0 = 62,5$	g mm	Example: G 2,5; n_{max}=6,000 1/min; m_R=30 kg $\rightarrow$ Permissible unbalance from neglect

Wellen-durchmesser d über / bis [mm]	Passfeder DIN 6885 b [mm]		h [mm]	Gewicht des Kopfspiels in der Nabe pro mm [g/mm]	Schwerpunkt-radius [mm]	
38 / 44	12	x	8	0,028	$d/_2$	+3,15
44 / 50	14	x	9	0,033	$d/_2$	+3,65
50 / 58	16	x	10	0,038	$d/_2$	+4,15
58 / 65	18	x	11	0,057	$d/_2$	+4,20
65 / 75	20	x	12	0,063	$d/_2$	+4,70
75 / 85	22	x	14	0,069	$d/_2$	+5,20
85 / 95	25	x	14	0,079	$d/_2$	+5,20
95 / 110	28	x	16	0,088	$d/_2$	+6,20
110 / 130	32	x	18	0,100	$d/_2$	+7,20
130 / 150	36	x	20	0,113	$d/_2$	+8,20
150 / 170	40	x	22	0,126	$d/_2$	+9,20
170 / 200	45	x	25	0,141	$d/_2$	+10,20
200 / 230	50	x	28	0,157	$d/_2$	+11,20
230 / 260	56	x	32	0,176	$d/_2$	+12,20

Table 6.4: Mass (steel) and geometry values for head clearance error

Example for the evaluation of the parallel key head clearance neglect

Shaft d=45 mm; parallel key 14x9; seat length 112 mm; material: steel;
balancing grade G 2,5; max. operating speed n_{max} = 6,000 1/min; rotor weight (hub + brake disc): 30 kg

Unconsidered mass of the key head clearance in the hub according to table and seat length:

$$0,033\ \frac{\text{g}}{\text{mm}} \cdot 112\ \text{mm} = 3,696\ \text{g}$$

Unbalance from mass and center of gravity of head clearance

$$3,696\ \text{g} \cdot \left(\frac{45}{2} + 3,65 \right)\ \text{mm} = 97\ \text{g mm}$$

Permissible unbalance with regard to the head clearance error

$$U_{K,per} := 62\ \text{g mm}$$

➔ In relation to the hub + brake disc assembly, the permissible unbalance is significantly exceeded by neglecting the key head clearance during balancing before grooving.

Consequently, an alternative balancing procedure with consideration of the head

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clearance is required.

7 Balancing corrections

The balance correction corrects rotationally asymmetrical form and position deviations in the component in relation to the center of mass. Therefore, a "large correction" always indicates large deviations in the component, which should then be checked.

7.1 Correction by material removal

Usually, balance correction is always performed by material removal. Other methods must be agreed with DBG.

Material removal, e.g. by drilling, must not impair the function of the component. Usually, holes are drilled on the axial face or radially on a rotating part.

The distance to parallel and through holes should be at least 0.5 times the bore diameter (web width). Holes which weaken the cross section should also be avoided in the area of the keyway in the hub.
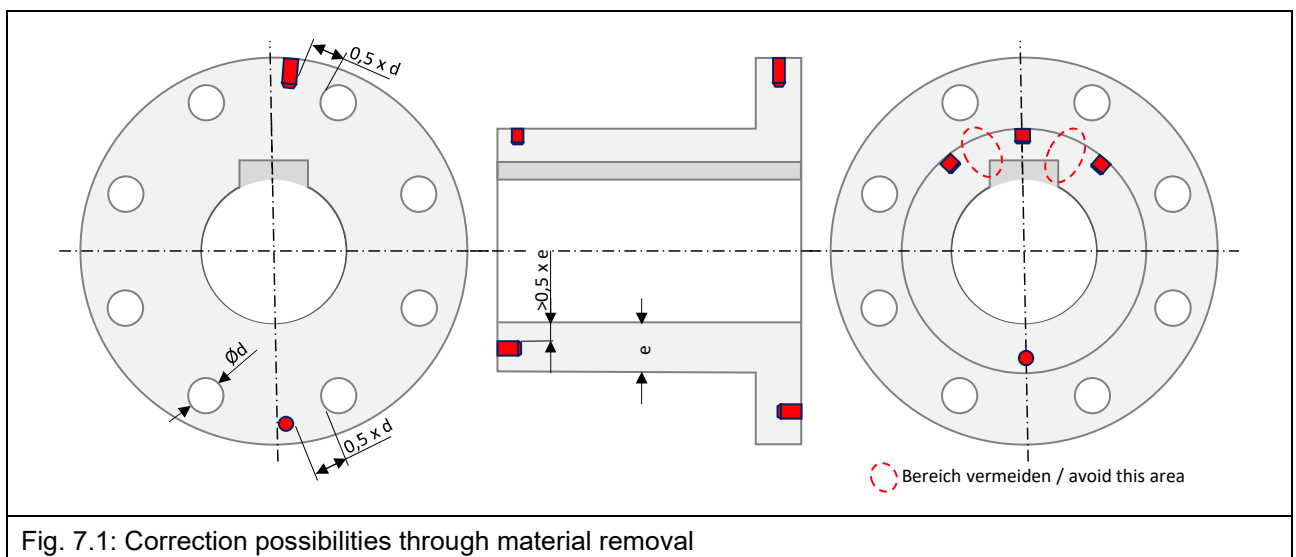

Fig. 7.1: Correction possibilities through material removal

All balancing holes must be deburred before final balancing to prevent injuries during handling.

7.2 Closure of balancing holes

If specified in the order, the holes for balance correction must be closed unless they are covered after assembly. There are two possible procedures for this:

1 Use of resin (e.g. Biresin G26).
Note: To prevent the cap from flying out under centrifugal force, a form closure must be provided by a thread in the bore. Before casting with resin, clean and degrease the threaded hole to obtain maximum adhesion.

2 Use of polyamide screws
Screws acc. to DIN 84/ISO 1207 made of plastic 6.6 can be screwed in and the protrusion cut off with a sharp knife flat to the surface of the component.

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Appendix A

Coupling parts with reference axis for balancing process
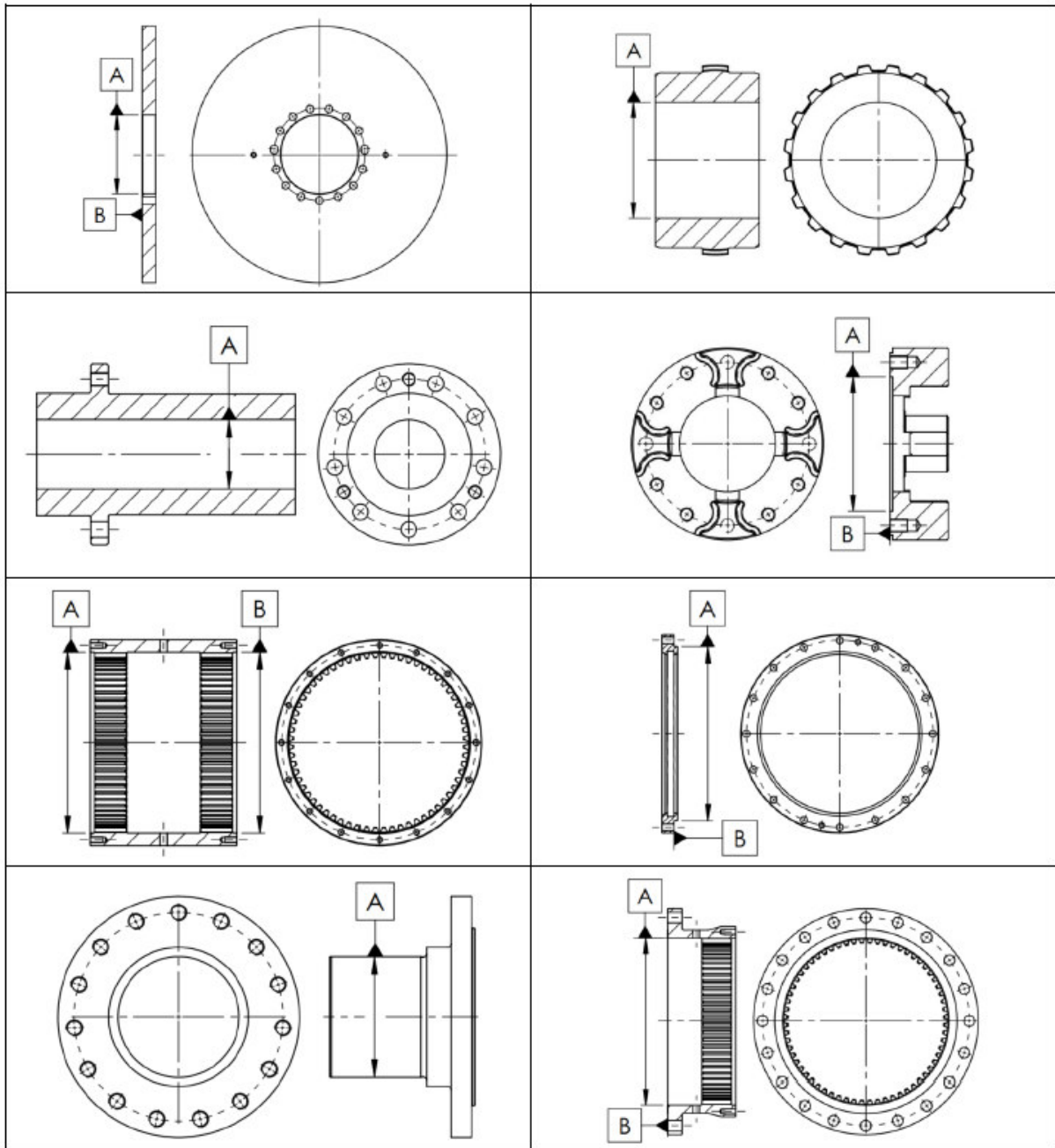
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