BALANCING

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INTRODUCTION

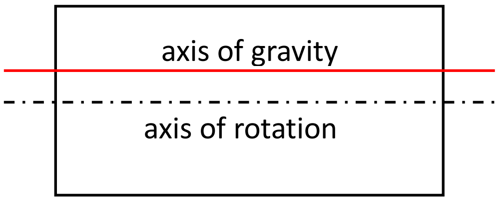
The experience of REGO-FIX AG in the development and manufacturing of tool holding systems has provided us a large knowledge basis on the subject of balancing. In our production we have the latest manufacturing equipment and testing methods available, but as with other manufacturers the physical limits of balancing have to be considered. Furthermore, it has to be considered whether a process is economically feasible and the imbalance measurable. The weights and interaction of the individual components of the tool holding system determines which options for balancing are practical. Therefore, we would recommend that the entire assembly be considered as a whole, as it is stipulated in the DIN 69888.

WHAT IS IMBALANCE?

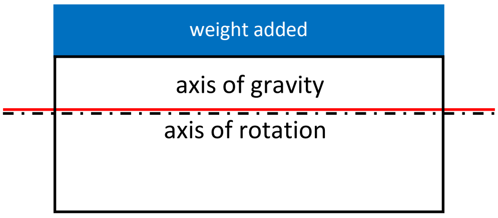
Imbalance occurs when the mass of a rotating body is not distributed rotationally symmetric. This leads to vibration and can cause increased wear or damage to cutting tools and or machine bearing components. The weight of each part of the tool holding system is critical to the question: At what speed is balancing economically producible? Speeds have a great influence on the centrifugal forces. Due to its nature the centrifugal force increase exponentially, which means when you double the speed you get four times the centrifugal force.

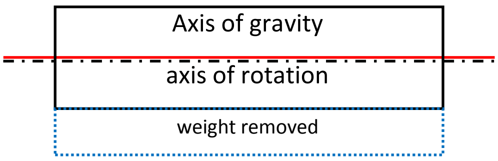
STATIC IMBALANCE

A static unbalance results when the axis of rotation does not pass through the center of gravity axis of the rotary body. The axis of rotation is parallel to the axis of gravity, but is displaced by some amount. This displacement (called eccentricity) produces a rotational circular vibration perpendicular to the rotational axis. This imbalance can be measured in a stationary position.



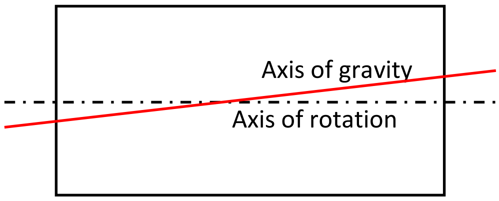
To reduce a static imbalance an appropriate weight is removed or adjusted perpendicular to the rotational axis.



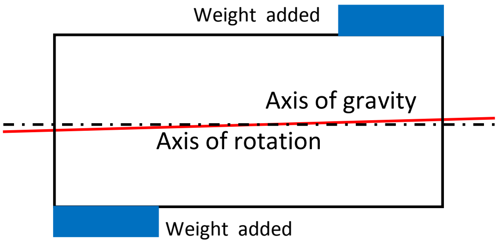


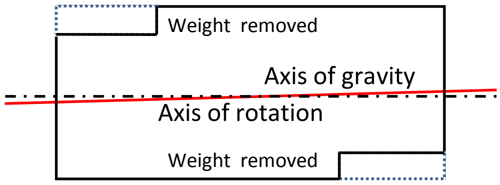
DYNAMIC IMBALANCE

Dynamic imbalance occurs only during operation. It manifests itself in an unbalanced moment on the axis of rotation producing coupled forces and orbital oscillations. The center of gravity of the rotating body is in the rest position, while the axis for the coupled forces rotates in circular motions.



To balance a dynamic imbalance, weight added, removed or adjusted at two levels.

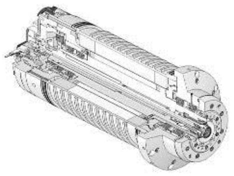




INFLUENCES ON THE IMBALANCE

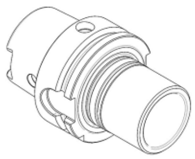
The whole toolholding system and spindle should be considered as well as any external influences such as dried-coolant film or dirt that has collected on the spindle. The weight of the individual components and the speeds are important factors to consider as well.

MACHINE SPINDLE



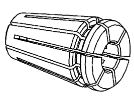
The spindle rotors are supported in the spindle housing in several locations and have for the most part a weight of about 15 kg. Therefore, they can be balanced much more accurately than a small rotating body such as a toolholder of only 200 g.

TOOL HOLDER



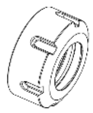
The toolholder is the largest component in the interface between the spindle and the tool. These are balanced according to the manufacturer at the factory.

COLLET



These are usually rotationally symmetrical parts and do not have to be balanced. Installation error (eg. not correct clamping) or pollution (chips, dried coolant etc.) can cause an imbalance.

CLAMPING NUT



These are balanced according to manufacturer. Dirt, debris or damage can cause an imbalance.

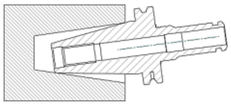
ACCESSORIES FOR CLAMPING SYSTEM

Accessories, such as coolant tubes, stop screws, pull studs, sealing and cooling disks may cause an additional imbalance.

TOOL

Cutting tool design may (eg, single-edged, Weldon clamping surface, etc.) already have an imbalance.

POSTIONING ERROR / TAPER FIT



The tool change position accuracy of tool holders can play a large role in the balancing and repeatability of the measured imbalance. An HSK holder has a position repeatability of between 2-4 microns while most steep taper holders can be up to 5 microns. Impurities on the cone or on the mating surface between the tool holder and the spindle can also lead to an imbalance and larger position inaccuracies.

Using a HSK-A 63 / ER 32 x 080 holder lets determine the effects of this positioning error.

The equation below is used to calculate the permitted position eccentricity when we know the residual imbalance and the holder weight. We will use this to calculate the residual when we know the eccentricity and weight.

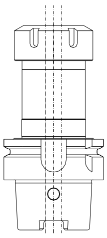
$$e_{zul} = \frac{U_{zul}}{M}$$

e_{zul}	Permitted eccentricity (µm)
U_{zul}	Permitted residual unbalance of the rotor (gmm)
M	Weight of the rotor (kg)

We will use a position accuracy of 2.5 µm and a holder weight of 1.035Kg

$$2.5\ \mu m = \frac{\text{residual unbalance}}{1.035}$$

Solving for unbalance yields a value of 2.59 gmm of potential inbalance just from positioning.



This diagram shows the variability of the holder centerline in exaggerated form. This is the repeatability of the radial positioning of the holder.

So as can been it is very important to clean all surfaces thoroughly as to minimize the position error that can occur.

BALANCING QUALITY

In recent years the cutting speeds have increased because of better materials and processes. This has resulted in new requirements on the balance of the whole system (machine spindle, clamping tool and tool).

NORMS

SELECTION OF DIN ISO 1940

This standard specifies the requirements on balancing as regulated grades of rotors in a constant (rigid) state. This standard is not applicable for tooling systems for the following reasons entire:

Spindles, tool holder systems and cutting tools have, in contrast to other rigid rotors (such as electric motor armatures, etc.) essential differences:

a) Spindle, tool holder and cutting tool form a system with high temporal variation (for example, frequent tool change machining centers).

b) Due to the radial angle and tension-related inaccuracies a repeated change of tool in the spindle leads to a change in the balancing state of the entire system.

c) Fit tolerances of individual components (spindle, tool holder and cutting tool) set limits for balancing.

SELECTION OF DIN 69888:2008-09

This standard specifies balancing requirements for tooling systems with HSK 25 to HSK 100 according DIN 69063-1, DIN 69063-2, DIN 69063-5, DIN 69063-6, DIN 69893-1, DIN 69893-2, DIN 69893-5 and DIN 69893-6 firmly based on their particular operating speed. In this standard the HSK 125 and HSK 160 are not given any consideration, so it is recommended to apply the limits for HSK 100. Correspondingly, the standard tool for systems with interfaces and tapers such as ABS, CAPTO, KM, SK and cylindrical shank are used. Here, the type-specific aspects of the interfaces and holders are taken into account. The standard applies under the following conditions:

a) a) In the area of operating speeds the tool systems are considered to be rigid.

b) The limit of vibration mechanical stress is defined by the permissible bearing load of the machine spindle.

c) So as not to unbalance-related impairments in the production is given in compliance with the procedures specified in the standard requirements (load bearing and thus the vibration velocity).

IMPORTANCE OF BALANCE OF QUALITY

By balancing quality value G, the weight of the rotor (M), the speed (n) and the conversion factor (9549), the permissible residual unbalance U_{zul} is calculated in gmm. It tells us how much mass asymmetrically distributed in the radial direction from the axis of rotation is still permissible. With the calculated value, the distance of this mass may be recalculated to gravitational axis.

FORMULAS

$$U_{zul} = \frac{G \times M \times 9549}{n}$$

U_{zul}	Permitted residual unbalance of the rotor (gmm)
G	Balance quality
M	weight of the Rotors (kg)
n	speed of the rotors
9549	Conversion factor

$$e_{zul} = \frac{U_{zul}}{M}$$

e_{zul}	Permitted eccentricity (µm)
U_{zul}	Permitted residual unbalance of the rotor (gmm)
M	Weight of the rotor (kg)

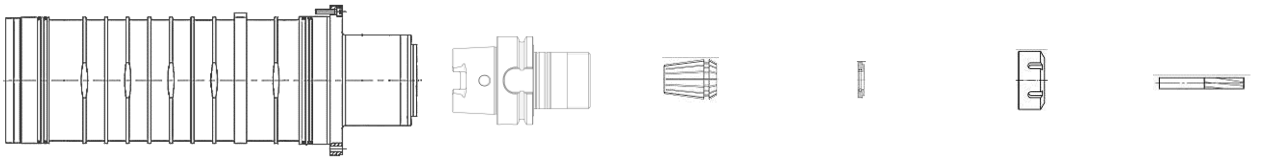
$$u = \frac{U_{zul}}{R}$$

u	Unbalance mass on the largest outer radius (g)
U_{zul}	Permitted residual unbalance of the rotor (gmm)
R	Radius at which the balancing is done

COMPARISON

The comparison between the overall system and a single tool holder shall demonstrate that the balance of the individual component has a very small effect on the overall system.

OVERALL SYSTEM



Machine spindle für HSK-A 63 **15.000 kg**	Tool holder HSK-A63 ER32X080-H **1.035 kg**	Collet Hi-Q - UP / ERC 32 **0.150 kg**	Seal disk DS / ER 32 6.00 -5.50 **0.015 kg**	Clamp nut Hi-Q ERC 32 6.00 – 5.00 **0.168 kg**	Cutter with internal cooling ø 6 mm **0.030kg**

Weight:	16.398 kg	
Radius (R)	31.5 mm	
Speed:	10’000 rpm	42’000 rpm
Balance quality (G):	2.5	2.5
Permitted residual unbalance (U_{zul}):	39.146 gmm	9.321 gmm
Permitted eccentricity (e_{zul}):	2.387 µm	0.568 µm

$$U_{zul10000} = \frac{2.5 \cdot 16.398 \cdot 9549}{10'000} = 39.146 \text{ gmm}$$

$$U_{zul42000} = \frac{2.5 \cdot 16.398 \cdot 9549}{42'000} = 9.321 \text{ gmm}$$

$$e_{zul10000} = \frac{39.146}{16.398} = 2.387 \text{ µm}$$

$$e_{zul42000} = \frac{9.321}{16.398} = 0.568 \text{ µm}$$

$$u_{10000} = \frac{39.146}{31.5} = 1.2 \text{ g}$$

$$u_{42000} = \frac{9.321}{31.5} = 0.3 \text{ g}$$

By calculation the entire system is allowed 1.2 g at 10,000 rpm and 0.3 g at 42,000 rpm and the permissible unbalanced mass is at its greatest diameter (in this case the spindle rotor).
The following calculation is used to demonstrate how little unbalanced mass of a tool holder HSK-A 63 / ER32 x 080 is acceptable in comparison to the overall system:

TOOL HOLDER HSK-A 63 / ER32X080 H

Weight:	1.035 kg	
Radius (R)	31.5 mm	
Speed:	10’000 rpm	42’000 rpm
Balance quality (G):	2.5	2.5
Permitted residual unbalance (U_{zul}):	2.471 gmm	0.588 gmm
Permitted eccentricity (ezul):	2.471 µm	0.588 µm

$$U_{zul10000} = \frac{2.5 \cdot 1.035 \cdot 9549}{10'000} = 2.471 \text{ gmm}$$

$$e_{zul10000} = \frac{2.471}{1.035} = 2.387 \text{ µm}$$

$$u_{10000} = \frac{2.471}{31.5} = 0.078 \text{ g}$$

$$U_{zul42000} = \frac{2.5 \cdot 1.035 \cdot 9549}{42'000} = 0.588 \text{ gmm}$$

$$e_{zul42000} = \frac{0.588}{1.035} = 0.568 \text{ µm}$$

$$u_{42000} = \frac{0.588}{31.5} = 0.019 \text{ g}$$

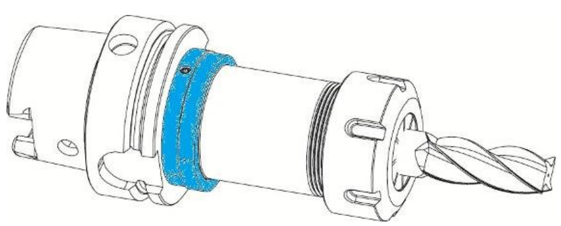
If now the allowable imbalance masses are compared, it is evident that in the overall system may be about 15 times larger than in the tool holder alone. The current state of balancing technology is not economically producible when just looking at the tool holder, but when the entire system is considered it may not necessary. In the next chapter, "BALANCING IN REGO-FIX®" including the "FINE BALANCE WITH HI-Q® BALANCING RINGS" is described with which the whole tool holder system (holder, collet, nut, cutting tools and accessories) can be finely balanced as a whole. An imbalance caused by positioning error can't be corrected or accounted for.

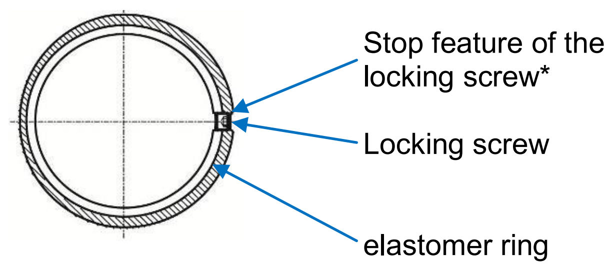
BALANCING AT REGO-FIX® AG

All tool holders and clamping nuts from the production of REGO-FIX® are balanced at the factory by design. In addition, the tool holders are fine balanced and 100% customized. The balancing data refer only to the tool holder. Most REGO-FIX® tool holders are designed to accommodate the REGO-FIX® HI-Q® balancing rings for fine balancing when required.

FINE BALANCE WITH HI-Q® BALANCING RINGS

REGO-FIX® HI-Q® balancing rings (patented) are mounted on the grooves designed into the tool holder, making all the clamping system (holder, nut, tool, etc.) balanceable.





* The locking set screw has a feature that prevents it from baking out and being thrown into the machine, which can at high speeds and the resulting centrifugal forces cause serious injury and damage to machinery.

DETAILS OF THE BALANCE VALUES OF TOOLHOLDERS

The stated REGO-FIX® balance values (packaging, catalogs, brochures, etc.) are the actual measured values from the balancers, which are the current state of the art.

STEEP CONE TOOL HOLDER

These tool holders are in production on a Level (static) as standard balanced at:

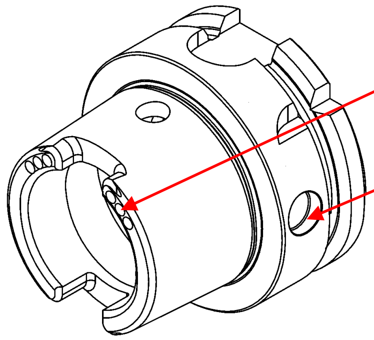
- TC 30, BT 30, BT-OM 30, BT+ 30 und CAT 30 — balanced to 30'000 rpm
- TC 40, BT 40, BT+ 40 und CAT 40 — G2.5 @ 22'000 rpm *
- ISO 20 (HAAS) — balanced to 40‘000 rpm

CAPTO TOOL HOLDER

These tool holders are in production on a Level (static) as standard on G2.5 @ 25'000 rpm balanced.*

HSK – TOOL HOLDER

These tool holders are balanced by a special process (Pat. pend.), in which two axially spaced staggered levels material ablated.



- HSK 25 balanced to 90'000 rpm
- HSK 32 balanced to 60'000 rpm
- HSK 40 balanced to 45'000 rpm
- HSK 50 balanced to 36'000 rpm
- HSK 63 G2.5 @ 25'000 rpm*
- HSK 80 G2.5 @ 25'000 rpm*
- HSK 100 G2.5 @ 25'000 rpm*
- HSK 125 G2.5 @ 12'000 rpm*

* Other balance qualities are available on request at an additional cost. It can't be guaranteed that these values are reproducible due to positioning error and taper fit. See the section on Positioning Error and Taper Fit for more details.

HI-Q® - CLAMPING NUT

The REGO-FIX Hi-Q - clamping nuts are balanced due to its design (patented) and are continuously tested during production.

COLLETS

Collets are rotationally symmetric and do not require balancing.
To enable the best possible concentricity collets must be cleaned before each use.

ACCESSORIES (SEALING DISCS, COOLANT DISCS, ETC.)

These are rotationally symmetric and do not require balancing.
To enable the best possible concentricity the accessories must be cleaned before each use. By improper handling or installation can lead to imbalance.

