

These working instructions specify the limit values for the bearing vibrations of machines in the testing field and the alarm and switch-off values in operation based on ISO 14694, BV-3 or BV-4. The stricter limit values for rigid configuration are generally used as the basis for the operating limit values instead of the values for elastic configuration permissible in accordance with the standard.

In the case of speed-controlled fans, the limit values of the next-lowest category apply in the control range outside the designed operating points.

## 1. Standard Values

The basis are Tables 4 of the ISO 14694 for elastic configuration during tests at the manufacturing plant (with installation on vibration dampers: original damper, test plate (vibration foundation)) and Table 5 of ISO 14694 for rigid configuration during on-site tests (regardless of the elasticity of the configuration)

Note: In contrast to ISO 14694, which only requires compliance with the limit values for the speed-dependent vibration values for measurements at the manufacturer's plant, sums are still used as the basis at the Moringen plant.

Table 1: Limit values for the bearing vibrations

Application	Category	Balance Quality G	Vibration Limit Values ( $\sum v_{\text{eff}}$ in mm/s)			
			Testing field	Operation		
				Commissioning	Alarm	Switch-Off
Industrial processes <sup>5</sup>	BV-3	6.3 (2,5)	3.5	4.5	7.1	9.0
Petrochemicals ATEX (P>37kW)	BV-4	2.5	2.8	3.5	4.5	7.1
Control range (outside design points)	BV-3	6.3 (2,5)	5.6	5.6		
	BV-4	2.5	3.5	4.5		
Fans with belt drive (P<160kW)	BV-2	6,3	5,6	5,6	9,0	11
VAPOFAN (PG 71)	BV-3	2,5	4,5 <sup>3</sup> (15) <sup>4</sup>	5,6 <sup>3</sup>	7,1 <sup>3</sup>	9,0 <sup>3</sup>

### Note:

- 1) Fans according to category BV-3 can also be balanced according to the domestic specification according to the G 2.5. However, this has no influence on the permissible vibration limit values, as indicated in Table 1.
- 2) Fans of the "petrochemical" application type and a power < 37 kW are rated according to category BV3 for the application "industrial processes".
- 3) The specified vibration limits refer to the released, usable speed range according to the motor data sheets. Vibration monitoring is only active in the enabled speed range, see locking diagram.
- 4) The vibration limit value given in brackets applies exclusively to the non-approved speed range, see document 59.6.384.0420. Compliance with this limit value must always be verified during commissioning / acceptance in the test field..
- 5) Including belt driven fans of the type 52570 RXGAEQ 80200 with a maximum speed of 12500 min<sup>-1</sup>.

**In the sales contract, the contractually agreed category shall be specified according to ISO 14694 and RL 59.9.384.3010**

Rev.:	Date	Description	Prepared	Checked	Approved
22	03.06.2024	Chap. 3 and 3.1: „ABB type series „M3BP 355LKB 2 3GBP351820-ADK, IE3“ with operating speed range 3000 - 3600 min <sup>-1</sup> “ added	Steinkamp	Köylü	Lakemann
23	17.01.205	Chap. 3.1.1: Various modifications added	Kolle	Köylü	Lakemann

## Explanation of 1. "Standard value"

Attention must be paid to the following for the purpose of defining the standard values:

1. Elastic configuration.  
The lower limit of the control range must be 20 % above the intrinsic frequencies of the (rigid) complete system of machine and substructure. This system must be calibrated very low if necessary (e.g. with spring dampers from GERB).
2. Pedestals and base frames must be rigid and resonance-free in the control range (with attached parts). If in doubt, this must be proven by Development with a finite element calculation.  
See also directive [59.9.384.2600](#) – Construction of blocks.

## 2. Special cases

### 2.1 Large machines with speeds < 1000 min<sup>-1</sup> for rigid configuration

(lowest intrinsic frequency of entire system consisting of machine and base: at least 25 % above the rotational frequency)

	Balance Quality G	Vibration Limit Values $\sum v_{\text{eff}}$ [mm/s]			
		Testing field	Operation	Alarm	Switch-Off
Standard:	BV-3	6.3	2.8	4.5	7.1
	BV-4	2.5	1.8	4.5	7.1

#### Specification in sales order:

Bearing vibrations of the fan on delivery according to ISO 14694

	BV-3	$v \leq 2,8 \text{ mm/s}$	(balance quality G 6.3)
or	BV-4	$v \leq 1,8 \text{ mm/s}$	(balance quality G 2.5)

### 2.2 On machines with monitoring of shaft vibration, the following also applies

Balance quality: **G2.5**

<u>Squeeze oil dampers</u>	Run-out	Testing field	Vibration monitoring	
Permitted sum values			Alarm	Switch-Off
$\sum [\mu\text{m}]_{\text{p-p}}$	< 20	40	50	70

The permitted sum values, measured in  $[\mu\text{m}]_{\text{p-p}}$  (peak to peak), must be observed within the entire speed range from 0 to maximum speed. The maximum permitted operating speed is specified in the order confirmation. Proof must be provided by recording the sum value as a local curve (sum value = f (phase angle)) with meaningful specification of the speed.

#### Sleeve bearings (DIN ISO 7919-3)

$\sum [\mu\text{m}]_{\text{p-p}}$ , speed n [min <sup>-1</sup> ]	< 1,200/ $\sqrt{n}$	4,800/ $\sqrt{n}$	9,000/ $\sqrt{n}$	13,200/ $\sqrt{n}$
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Table 2: Limit values for the maximum shaft vibration  $[\mu\text{m}]_{\text{p-p}}$  and the maximum interference vibrations ("run-out") in the case of sleeve bearings large motors (> 1,000 kW) as per DIN EN 60034-14

Vibration level	Speed range	Maximum relative shaft vibration displacement	Maximum sum of electrical and mechanical interference vibrations (run-out)
	min <sup>-1</sup>	$\mu\text{m}_{\text{p-p}}$	$\mu\text{m}_{\text{p-p}}$
A	>1800	65	16
	≤1800	90	23
B	>1800	50	12.5
	≤1800	65	16

NOTE 1 Machines of the vibration-variable strength level "B" are frequently intended for fast-running drives with critical installation conditions.

NOTE 2 The limit values for the maximum relative shaft vibration displacement contain the run-out. For a definition of the run-out, see ISO 7919-1

**Operational balance** is performed if the limit values are exceeded for bearing and motor vibrations or in the event of higher rotational frequency vibrations (more than **50 %** of the broad band vibration limit). Operational balance must be documented

The specified limit values apply to tested machines in the testing field and during commissioning. The SO texts (entry with text blocks) are the contractual basis.

Directive 59.9.384.3011 is eliminated.

**In the sales contract, the contractually agreed category shall be specified according to ISO 14694 and RL 59.9.384.3010**

### **2.3 Special machines with balance quality G1.0**

Rotors of fans with tapered pressed connections fitted with control can be balanced to balance quality G 1.0 at the balancing speed and with the original shaft. Balance quality G 2.5 applies outside of the balancing speed. Limit values as per Table 1 Category BV-4 apply for bearing vibrations.

## **3. Motors**

Due to their vibration behavior, motors whose maximum speeds are above  $3600 \text{ min}^{-1}$  require special treatment with regard to testing and the permissible vibration values. Knowledge of this is from operational experience, supported by our own calculations and discussion with the manufacturers (ABB, Siemens Loher).

The design of these "high-speed" motors has been multiply uprated from the standard motors (50/60 Hz), and their rotors and the bearing have been adjusted to the speed requirements. However, the motor casings remain unchanged in many cases (cast construction). This results in a reduction in the distance of the intrinsic frequencies to the maximum operating speed. In extreme cases, there may be intrinsic frequencies in the speed range of the motor.

The position of the intrinsic frequencies is determined by the rigidity of the motor casing and the underlying surface on which the motor is mounted. Testing of motors with rigid clamping assumes a rigid foundation or a below-resonance test plate, so that the intrinsic frequencies of the motor is not influenced by additional elasticities. If, on the other hand, the motor is mounted into a fan construction, then the inherent frequencies are lowered by the elasticity of the construction. Consequentially, the limit values required by DIN EN 60034-14, vibration level A, cannot be met in many cases when testing the complete system comprised of fan with motor. Compliance with the values can only be achieved by increased requirements with regard to the permitted vibration values, which must be verified within the framework of testing with "rigid clamping".

Although the motors of the ABB type series "M3BP 355LKB 2 3GBP351820-ADK, IE3" are not "high-speed" motors, they also require special treatment if they are operated in the operating speed range  $3000 - 3600 \text{ min}^{-1}$ . This knowledge results from operating experience in the Moringen test field.

### **3.1 Requirements for motors with maximum operating speeds $> 3600 \text{ min}^{-1}$ or ABB type series "M3BP 355LKB 2 3GBP351820-ADK, IE3" with operating speed range $3000 - 3600 \text{ min}^{-1}$**

**The requirements for the technical design are as follows:**

- The lowest natural frequency (tilting vibration perpendicular to the axis of rotation) of the motor, mounted or clamped on a rigid foundation or on a deeply tuned test plate, must be at least 25 % above the maximum operating speed of the motor, see DIN EN 10816-3.
- The first bending natural frequency of the motor must be at least 35 % above the maximum operating speed of the motor, see DIN EN 10816-3.

The natural frequencies are given by the supplier in the offer/order confirmation.

The motor must be equipped on both bearing levels with balancing discs accessible from the outside, which allow the motor rotor without dismantling.

#### **3.1.1 Special case: motors with sleeve bearings**

The natural modes of the motors are excited by the unbalance of the rotor. Due to the significantly higher damping properties of sleeve bearings compared to rolling bearings, the excitation of the natural modes of motors with sleeve bearings is significantly lower. Numerical frequency passage analyzes show that the calculated vibration speed on the motor housing is below the alarm or shutdown values. Figure 1 shows the vibration speeds calculated using an

FEM analysis on the motor housing of a 500 kW motor with sleeve bearings. The calculation was carried out for an increased balancing grade of  $G = 6.3 \text{ mm/s}$ . The calculated maximum swing speed is approx.  $2.7 \text{ mm/s}$ .

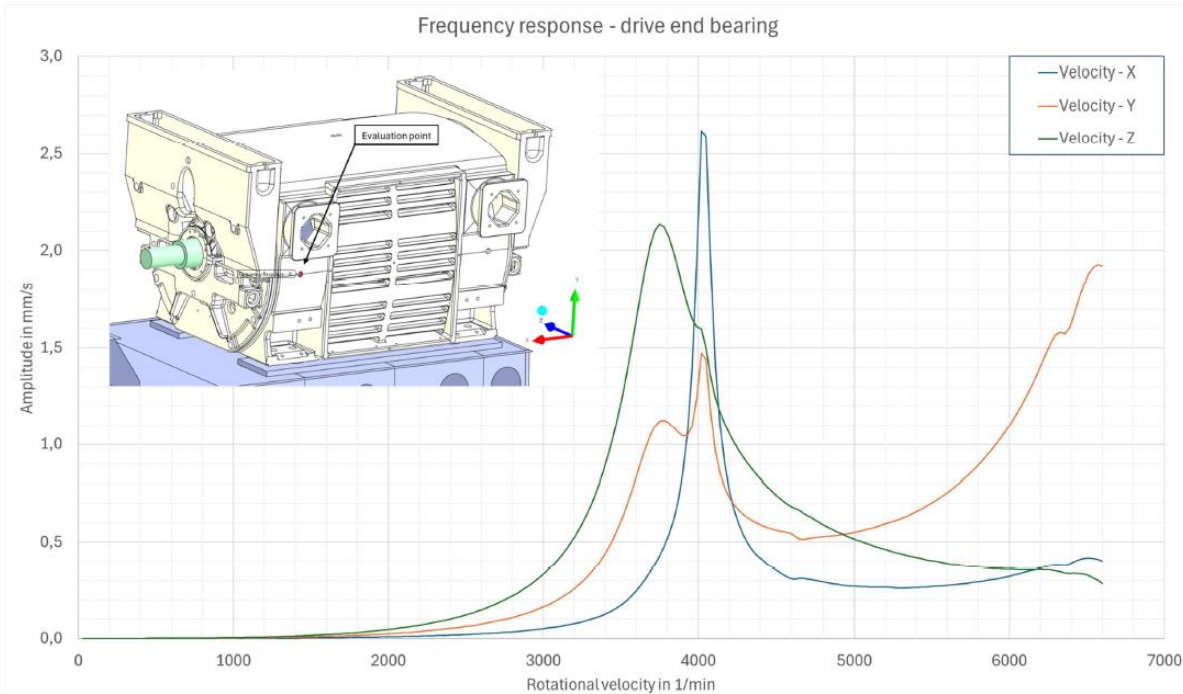


Figure 1: FEM calculation of the excited vibrations of a 500 kW motor with sleeve bearings

The requirements for motors with sleeve bearings are as follows:

YY There are no special requirements concerning the natural frequencies and the critical speeds. The natural frequencies and the critical speeds are to be advised by the supplier with the offer/order confirmation.

The balancing grade of the motor shaft must be  $G = 1 \text{ mm/s}$  or better. The motor must be equipped on both bearing levels with balancing discs accessible from the outside, which allow the rotor to be balanced without dismantling.

Documentation of the test run at the manufacturing shop (measurement of the vibration displacement and vibration velocity during run-up and coast-down) is mandatory. The results should be presented in the same way as shown in Figure 1 and send to Piller.

The motor should be monitored during operation regarding the limit values for the vibration. Therefor are the minimum requirements:

Monitoring is carried out by measuring the vibration velocity in the horizontal direction at both bearing planes on the motor housing. The manufacturer must provide suitable threaded holes near each bearing plane. The limit values for alarm and shutdown must be advised by the supplier with the offer/order confirmation and must be included in the motor data sheet.

For example, the following sensors can be used:

- 10620523 – Schwingungsmonitor PCH1270/CHF8438L10
- 10647774 – Geschwindigkeitsaufnehmer HE200.00.16.00

Alternatively, monitoring can be carried out by measuring the vibration displacement on the motor shaft in both bearings. In this case, the measurement is carried out in at least two directions. The limit values of the vibration displacement must be advised by the supplier with the offer/order confirmation and must be included in the motor data sheet. YY

### 3.1.2 The requirements for type testing in the manufacturer's works, if the aforementioned technical design requirements are fulfilled:

- The motor is mounted on a rigid or deeply tuned test plate using the specified screws and torques. A load less test run (run-up or coast-down) from 0 - 100 % of the maximum operating speed is carried out at manufacturer's shop floor
- During this test run the effective bearing vibrations  $v_{\text{eff}}$  (mm/s) at both bearing planes in horizontal and vertical direction shall be measured and recorded. The effective bearing vibrations must meet vibration level A according to DIN EN 60034-14, 2019 in the speed range of from 0 - 100 %, see Table 3.
- If the effective bearing vibrations are not within the limits, the balancing quality of the motor rotor has to be corrected.
- The Vibration recordings are part of the motor documentation.

### 3.1.3 The requirements for type testing at the manufacturer's works if the aforementioned technical design requirements with regard to the lowest natural frequency of the motor are not fulfilled:

- The motor is mounted on a rigid or deeply tuned test plate using the specified screws and torques. A load less test run (run-up or coast-down) from 0 - 100 % of the maximum operating speed is carried out at manufacturer's shop floor.
- During this test run the effective bearing vibrations  $v_{\text{eff}}$  (mm/s) on both bearing planes in horizontal and vertical direction are measured and recorded. The effective bearing vibrations must be within vibration level A according to DIN EN 60034-14, 2019 in the speed range of 0 - 100 % and within level B according to DIN EN 60034-14, 2019 in the speed range of 70 - 100 %, see Table 3.
- If the effective bearing vibrations are not within the limits, the balancing quality of the motor rotor has to be corrected. A correction of the balancing quality at the balancing discs accessible from the outside is not permissible
- The vibration recordings are part of the motor documentation.

Table 3: Limit values (sum effective value) of the max. vibration quantity for vibration displacement (s), Vibration velocity (v) and vibration acceleration (a) for the axle height H

Vibration size stage	axle height H mm	$56 \leq H \leq 132$		$H > 132$	
	Machine placement	$S_{\text{eff}}$ $\mu\text{m}$	$V_{\text{eff}}$ mm/s	$S_{\text{eff}}$ $\mu\text{m}$	$V_{\text{eff}}$ mm/s
A	rigid clamping	-	-	37	2,3
B	rigid clamping	-	-	24	1,5

Deviations from these limits must be approved by the quality department of Piller Blowers & Compressors GmbH. The results of these type tests must be sent to Piller Blowers & Compressors GmbH as a pdf document to [gm@piller.de](mailto:gm@piller.de) for inspection and approval before delivery.

The following note must be given in the order text for the respective motor: Order according to guideline 59.9.384.3010, bearing vibrations - limit values. The test documentation must be sent to Piller Blowers & Compressors GmbH as a pdf document before delivery to [gm@piller.de](mailto:gm@piller.de) for inspection and approval. A delivery without the present release by the quality department of Piller Blowers & Compressors GmbH is not permitted.

## 3.2 Incoming goods inspection for engines

In principle, the result documentation according to 3.1 must be submitted to the quality department of Piller Blowers & Compressors for delivery release. If no delivery release has been issued for a delivered motor, then this motor can be subjected to an extended incoming goods inspection in the in-house test field.

In the course of this incoming goods inspection, the motor is clamped on a deeply tuned test plate and subjected to an inspection as described under 3.1. The records for this incoming inspection are stored in the "Test field" folder of

the document control in a new "WE-Motor" folder to be created. The documents are marked in accordance with the specifications in Directive 59.9.384.0040.

If the specified limit values are exceeded, an "SV" must be created in accordance with 59.9.702.8002, which initiates early troubleshooting (reworking by the supplier) so that the motor is available in a serviceable condition at the time of assembly.

**The costs for the extended incoming goods inspection shall be borne by the supplier.**

In addition, it is incumbent upon the QW to subject the test results available from the supplier to an inspection by a counter-checking incoming inspection by specifying a random sample inspection. If the warranted characteristics are not achieved, the supplier shall bear the costs for the repair (two-plane balancing) of the motor.

### **3.3 Testing of the motors in the test field of Piller Blowers & Compressors GmbH**

After successful incoming goods inspection, the motors are released for further internal use and generally mounted on the fan for testing the fan.

Within the scope of the fan test, the effective values of the selective and the total vibration velocity in the speed range of 0 - 100 % of the maximum operating speed  $n_{Bmax}$  are recorded and documented at both bearing levels, in the horizontal and vertical direction.

If the permissible values in Table 1, Limit Values for Bearing Vibrations, are exceeded, the vibration behaviour of the motor can be improved by operating balancing on the externally accessible balancing discs. If this is not successful, then the motor will be complained about with a service procedure (SV). **The supplier shall bear the costs for this.**

### **3.4 Customer supplies and warranty**

The customer is obliged to pass on the specifications made here according to 3.1 as a basis for the procurement of the engine to his supplier.

Motors provided by the customer which do not comply with the specifications according to 3.1 can be used without limitation of the warranty if the critical speed range in which the permissible vibration values are exceeded is safely suppressed for the continuous operation of the fan.

**For this a proof is necessary, which is accomplished by the service of the Piller Blowers & Compressors and must be ordered.**

Piller Blowers & Compressors reserves the right to limit or, if necessary, **reject the warranty of the fan in respect of damage caused by unacceptable induced motor vibrations on the fan for motors provided by the customer which do not comply with the specifications according to 3.1 and are nevertheless used without restriction.** This includes damage to the coupling, the fan bearing, the impeller and fatigue damage to the substructure (fan bracket) and the fan housing. The basis for this is the risk assessment of the machine. The exclusion or limitation of the warranty or the delivery of an incomplete machine must be clarified explicitly with the customer in each individual case and must always be made in writing.

## **4. Gears**

### **Information on gears:**

Limit values for gears in no-load operation with fixed clamping according to DIN ISO 10816-1, Class III, Category "A": 2.8 mm/s. Balance quality G 2.5.

## **5. Appendix**

Document 59.9.384.3020 "Motors ABB-M3BC speeds" in the norm archive is available.

**Attention, this is an internal document and is only for information purposes within the company and must not be given to third parties!**