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Vacuum technology — Turbomolecular pumps — Measurement of rapid shutdown torque

Technique du vide — Pompes turbomoléculaires — Mesurage du couple d'arrêt rapide

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 27892 was prepared by Technical Committee ISO/TC 112, *Vacuum technology*.

Introduction

A rotating turbomolecular pump or molecular drag pump has a large amount of energy stored in the rotor due to the high rotational frequency. If the rotor breaks, this energy is released in a very short time and there is the possibility of rupture of the casing of the turbomolecular pump. A large reaction torque is also generated on the pump housing and there is a possibility that the bolts that fix the turbomolecular pump might break.

This International Standard is based on results compiled in studies of these possibilities and has been drafted as a measurement method by turbomolecular pump manufacturers with the aim of improving the safety of users.

The core contents of this International Standard are the test methods for rapid shutdown torque measurement of turbomolecular pumps and molecular drag pumps.

The term “turbomolecular pump” used in this International Standard is generic and includes molecular drag pumps and pumps which contain both technologies on the same shaft.

Vacuum technology — Turbomolecular pumps — Measurement of rapid shutdown torque

1 Scope

This International Standard specifies a method for the measurement of rapid shutdown torque (destructive torque) of turbomolecular pumps in which gas momentum is produced by axial flow type blades and/or helical channels. The main forces leading to failure of turbomolecular pumps are torques around the rotational axis. Other insignificant forces and moments that can occur lie outside the scope of this International Standard.

There are two kinds of failure: rapid shutdown by whole burst and softer crash of rotor. This International Standard applies to both. The same measurement method can be used for turbomolecular pumps and molecular drag pumps.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3529-2, *Vacuum technology — Vocabulary — Part 2: Vacuum pumps and related terms*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 3529-2 and the following apply.

3.1
inlet flange
turbomolecular pump inlet suction flange for connecting and fitting on to the vacuum vessel that is to be evacuated

3.2
rotor
rotational body
rotational parts
⟨vacuum pumps⟩ assembly, composed of shaft, rotor body and rotor blades, which is supported by bearings and is driven by a motor

3.3
rotor blade
turbine blade
rotating blade
⟨vacuum pumps⟩ part of a pump which rotates with a peripheral speed close to the speed of sound and which imparts a vacuum exhaust action to the pump, analogous to axial flow type turbine blades

3.4
rotor body
cylinder part of rotor
rotor hub
⟨vacuum pumps⟩ rotor assembly excluding the rotor blades

3.5
centrifugal destruction
split caused by centrifugal force
rupture caused by centrifugal force
failure occurring in the rotor body through circumferential tensile stress above the marginal value due to the centrifugal force acting on the rotor when operating

3.6
destructive test
rotor destructive test
test of the safety of the turbomolecular pump body and measurement of the destructive torque by causing the rotor body of the turbomolecular pump (burst test) or the rotor blades of the turbomolecular pump (crash test) to fail

3.7
destructive rotational frequency
rotational frequency of the rotor when the rotor body fails in the test

3.8
notch machining
machining carried out on all or a part of the rotor prior to destructive testing to form a notch so that an appropriate stress concentration occurs in the rotor body so that failure occurs in the vicinity of the rated rotational frequency separately stipulated for the rotor body during destructive testing

3.9
destructive torque
shutdown torque
rapid shutdown torque
rotational torque acting on or transmitted to the inlet flange fixing member side or base fixing side during failure of the rotor body by centrifugal force in destructive testing

4 Symbols, definitions, and units

Symbol	Definition	Unit
A	Cross-section of compression bar	m^2
d_1	Internal diameter of short tube	m
d_2	External diameter of short tube	m
E	Young modulus of elasticity of lengthwise direction of compression bar	Pa
F_n	Measured force	N
G	Modulus of rigidity of short tube	Pa
I_p	Initial moment of inertia of rotor around rotational axis	kg m^2
i	Compression bar number or force sensor number	
n	Rotational frequency	Hz
r	Location radius of compression bar or force sensor	m
T	Rapid shutdown torque	Nm
t	Time	s
ε	Measured strain	
ω	Angular velocity	rad/s

5 Destructive test methods for turbomolecular pumps

5.1 General

There are two kinds of failure: rapid shutdown by whole burst and softer crash of rotor. Pumps are fixed either at the inlet flange or the pump base. There are thus two kinds of destructive test equipment (see 5.4). The more suitable test method should be selected by the manufacturer based on the intended use of the product.

5.2 Items to be checked

WARNING —The destructive tests listed below are dangerous and adequate safety measures should be taken when carrying them out.

To ensure safety, measure rapid shutdown torque. This method is the only recommended method. The torque obtained by this method is not always the maximum value, but one value.

Check the following items:

a) the value of the destructive torque;

b) that the pump mounting uses the stipulated fitting and is safe;

c) that the pump housing is safe.

5.3 Test conditions for burst and crash (failure of rotor body and rotor blades)

The destructive test conditions are as follows.

5.3.1 Destructive test method (burst)

5.3.1.1 The rotor is deemed to fail when the rotor body or the main shaft fails.

5.3.1.2 The procedure involves notch machining of the rotor body or main shaft so that the rotor body fails by centrifugal or external (e.g. a “crash” destructive test method in which rotor or stator blades fail) force in the vicinity of the rated speed. The notch in the main shaft should be located between the rotating motor and the rotor mounting.

5.3.1.3 Make the notch with four or fewer divisions.

5.3.1.4 The rotational frequency at failure should preferably be within ± 5 % of the rated rotational frequency.

NOTE This International Standard does not make stipulations with regard to the division method of rotor body failure in destructive testing.

5.3.2 Torque cell

5.3.2.1 General

There are two types of torque cell, either consisting of a short tube with strain gauges (5.3.2.2) or a stand with compression bars (5.3.2.3). The compression bars have strain gauges or force sensors attached to them.

If a torque cell is used, ensure that plastic deformation of the cell does not occur.

5.3.2.2 Short tube type

5.3.2.2.1 The torque on the cell is measured by strain gauges, which are fitted to the central part of the short tube, as shown in Figure 1. The strain gauges are installed diametrically opposite one another. Figure 2 shows strain gauges in eight places (four sets) at a pitch of 30°. Other examples are shown in Figures 3 and 4. To ensure adequate responsiveness of the measurement system, it is desirable to use gauges with a range of 0 Hz to 10 kHz or more.

5.3.2.2.2 The destructive torque is calculated from the mean value of strain around the circumference at the time of failure.

The relation between torque, T, in newton metres, and strain is given by Equation (1).

$$T = \frac{\varepsilon \, G \, \pi \left(d_2^4 - d_1^4 \right)}{8 \, d_2} \qquad (1)$$

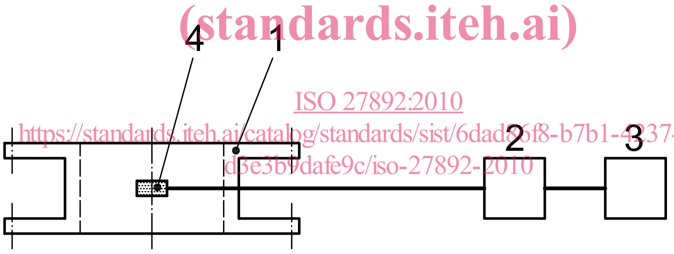
where

ε is the measured strain whose direction is at 45° with respect to the axis of the torque cell;

d_1 is the internal diameter, in metres, of the short tube;

d_2 is the external diameter, in metres, of the short tube;

G is the shearing modulus of rigidity, in pascals, of the short tube.



Key

1 short tube with strain gauges

2 amplifier for strain gauges

3 data recorder

4 strain gauges

Figure 1 — Short tube with strain gauges

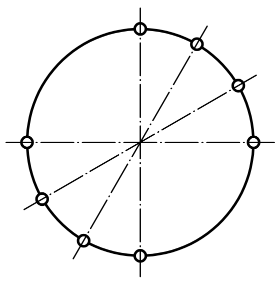


Figure 2 — Example of a pitch of 30°, eight places (four sets)

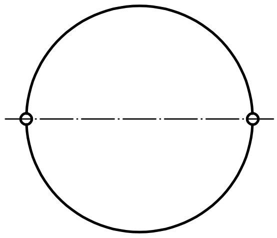


Figure 3 — Example of two places (one set)

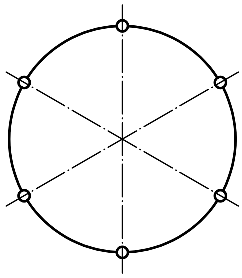


Figure 4 — Example of a pitch of 60°, six places (three sets)

5.3.2.3 Compression bar type

5.3.2.3.1 Compression bars are provided on a stand (see Figure 5) in the direction of action of the pump destructive torque. The bars are set up so that strain gauges or force sensors are compressed by the pump destructive torque. Compression bars with strain gauges are also known as strain rods. The strain rods or the force sensor are fixed to the floor or a base plate by fasteners such as anchor bolts that have sufficient strength.

5.3.2.3.2 The measurement gauge used for the compression bar torque cell is a strain gauge or a force sensor. The strain gauges or force sensors are installed on the compression bars as in 5.3.2.3.1. It is desirable to install compression bars at two to four places at equal intervals around the circumference. To ensure adequate responsiveness of the measurement system, it is desirable to use strain gauges or force sensors with a range of 0 Hz to 10 kHz or more.

5.3.2.3.3 The destructive torque is calculated from the sum of strain or force at the two to four places at the time of failure.

For strain gauges, the torque, T, in newton metres, is related to strain by Equation (2):

$$T = E\ A\ r\ \left(\varepsilon_1 + \ldots + \ \varepsilon_i\right) \tag{2}$$

where

ε_i is the measured strain;

A is the cross-sectional area, in square metres, of the compression bar;

E is the Young modulus of elasticity, in pascals, of the lengthwise direction of the compression bar;

i is the strain rod number;

r is the compression bar location radius, in metres.