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Reciprocating internal combustion engines — Performance —

Part 5: Torsional vibrations

Moteurs alternatifs à combustion interne — Performances —

Partie 5: Vibrations de torsion

Reference number
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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 3.

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 part of ISO 3046 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3046-5 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*.

This second edition cancels and replaces the first edition (ISO 3046-5:1978), which has been technically revised.

ISO 3046 consists of the following parts, under the general title *Reciprocating internal combustion engines — Performance*:

— *Part 1: Declarations of power, fuel and lubricating oil consumptions and test methods — Additional requirements*

— *Part 2: Test methods*

— *Part 3: Test measurements*

— *Part 4: Speed governing*

— *Part 5: Torsional vibrations*

— *Part 6: Overspeed protection*

— *Part 7: Codes for engine power*

Reciprocating internal combustion engines — Performance —

Part 5: Torsional vibrations

1 Scope

This part of ISO 3046 establishes general requirements and definitions for torsional vibrations in shaft systems of sets driven by reciprocating internal combustion (RIC) engines.

Where necessary, individual requirements can be given for particular engine applications.

This part of ISO 3046 covers sets driven by reciprocating internal combustion engines for land, rail-traction and marine use, excluding sets used to propel road construction and earthmoving machines, agricultural tractors, industrial types of tractors, automobiles and trucks, and aircraft.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 3046. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 3046 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 2041:1990, *Vibration and shock — Vocabulary*

ISO 2710-1, *Reciprocating internal combustion engines — Vocabulary — Part 1: Terms for engine design and operation*

ISO 2710-2, *Reciprocating internal combustion engines — Vocabulary — Part 2: Terms for engine maintenance*

3 Terms and definitions

For the purposes of this part of ISO 3046 the terms and definitions in ISO 2710-1 and ISO 2710-2 as well as the following apply.

3.1
set
assembly of mechanisms including one or more RIC engines and the driven machinery

3.2
shaft system
assembly of all the components of a set connected so that they can rotate (see Figure 1)

NOTE When the torsional vibrations are calculated, it is the complete shaft system that is considered.

3.3
torsional vibrations
oscillatory angular deformation (twist) of a rotating shaft system

3.4
torsional vibration amplitude
maximum angular displacement measured in a section perpendicular to the axis of the shaft system between the angular position considered and a given arbitrary reference position

3.5
natural frequency
parameter that can be calculated for each solution of the equation of motion for the undamped system

See 2.80 of ISO 2041:1990.

NOTE It is usually not necessary to calculate the natural frequency for a damped system.

3.6
natural vector
relative amplitude for the whole section where the system is vibrating at its associated natural frequency and an arbitrary section of the system is chosen as a reference and given an amplitude of unity

3.7
elastic line
envelope of the natural vector amplitudes in each section (see Figure 2)

3.8
vibratory node
point of elastic line where relative natural vector amplitude is equal to zero

3.9
natural mode of torsional vibration
natural frequency and its elastic line that characterizes each mode of torsional vibration

NOTE Examples are first mode of vibration or one node mode of vibration or second mode of vibration or two node modes of vibration.

3.10
excitation torque
torsional periodic torque generated by the RIC engine or driven components that excites torsional vibration of the shaft system

3.11
harmonic
each term of a series of sinusoidal terms (Fourier series) into which the excitation torque may be subdivided

See 2.26 of ISO 2041:1990.

NOTE Each of these harmonics is theoretically capable of producing resonance at the appropriate rotational velocity of the shaft system. The Fourier series terms are written in increasing order. The first harmonic is related to the first term of the series (even if it had zero magnitude) and so on (see Figure 3). The constant term is the mean torque.

3.12
vibration order
number of oscillations per revolution associated with each harmonic

NOTE For RIC engines operating on the two-stroke cycle, the vibration order corresponds to the range of the harmonic. For four-stroke engines, the range of the harmonic may be divided by two to obtain the corresponding vibration order; e.g. II/4 for the resonance speed at which the second mode of vibration is excited by the fourth order harmonic.

3.13
resonance speed
speed at which the whole shaft system resonates (as the natural frequency of a vibration mode equals the frequency of one of the harmonics of the excitation torques)

See 2.73 of ISO 2041:1990.

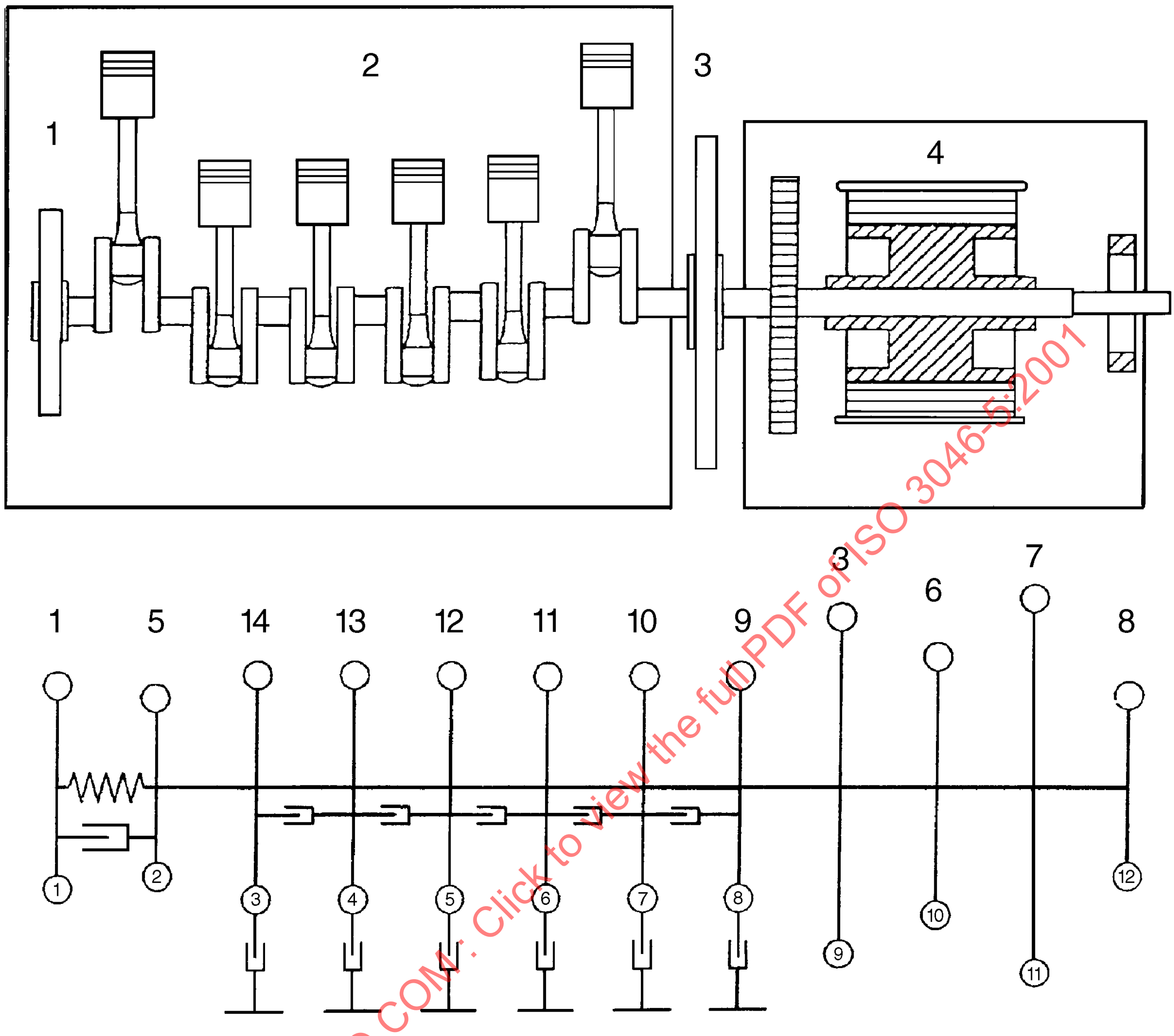
3.14
synthesized torsional stress
torsional stress generated in a given section of the shaft system by the total of all the harmonics of the excitation torques, taking account of the magnitude and phase of the stress generated by each harmonic (see Figure 4)

NOTE Mean torque is not used when elaborating the synthesized torsional stress.

3.15
additional torsional stress
stress due to the torsional vibrations of a given harmonic which is superimposed on the torsional stress corresponding to the mean torque transmitted in the given section of the shaft system being considered

3.16
barred speed range
speed range over which the stress caused by the torsional vibration exceeds the stress value permitted for continuous operation

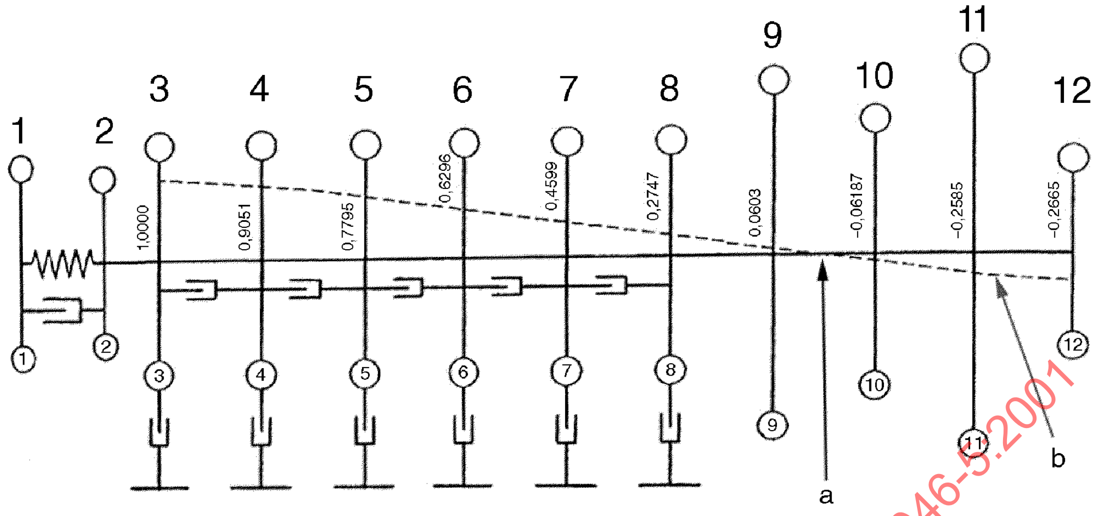
NOTE Continuous operation in this speed range is forbidden, but passing through in transient operation is permissible provided that it offers no danger or damage to the shaft system.



Key

1	Damper	8	Exciter
2	Engine	9	Cylinder 6
3	Flywheel	10	Cylinder 5
4	Alternator	11	Cylinder 4
5	Case	12	Cylinder 3
6	Fan	13	Cylinder 2
7	Rotor	14	Cylinder 1

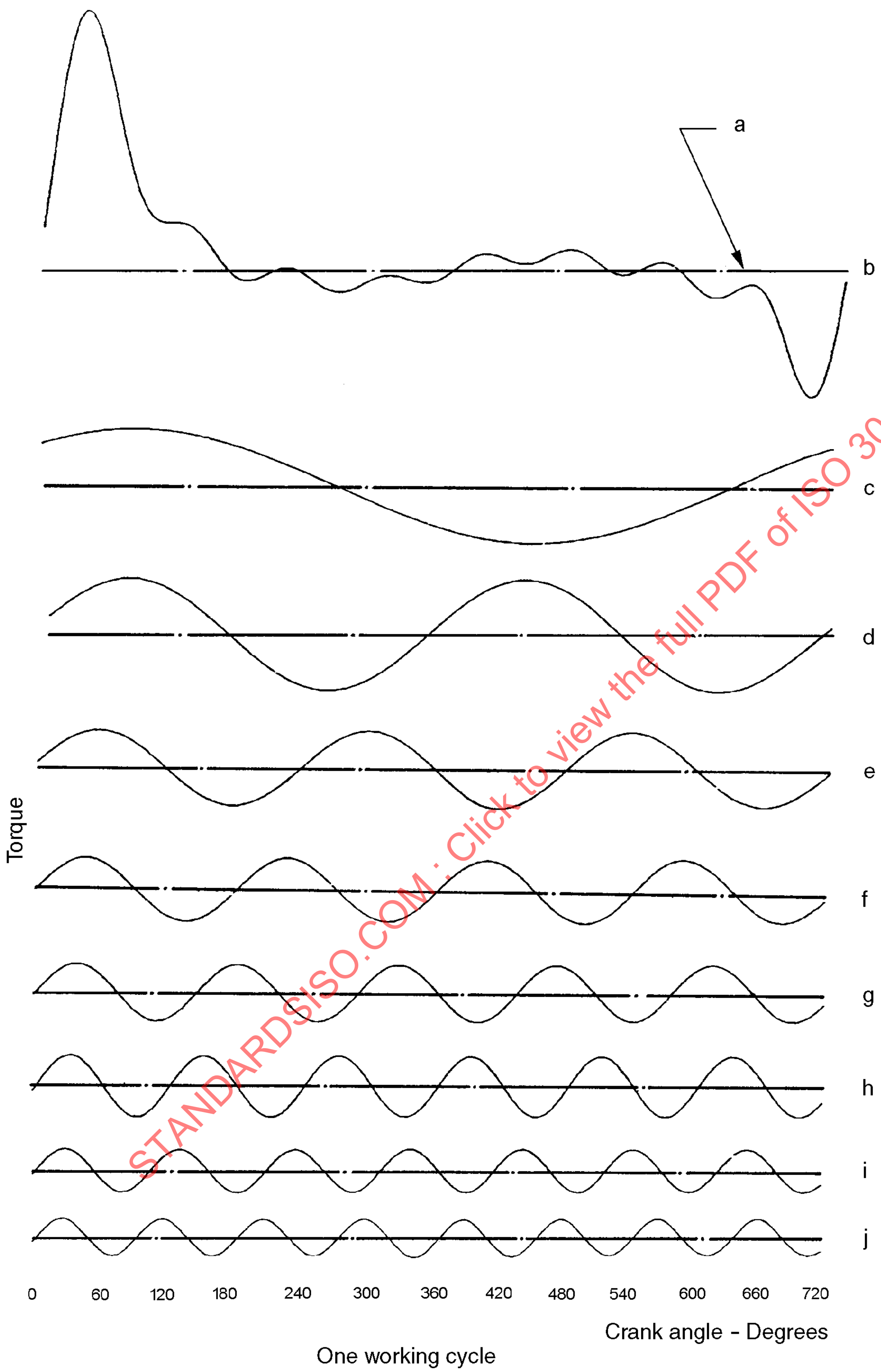
Figure 1 — Six-cylinder diesel engine and alternator and equivalent ideal system



Key

1 Damper
2 Case
3 Cylinder 6
4 Cylinder 5
5 Cylinder 4
6 Cylinder 3
7 Cylinder 2
8 Cylinder 1
9 Flywheel
10 Fan
11 Rotor
12 Exciter
a Node
b Elastic line

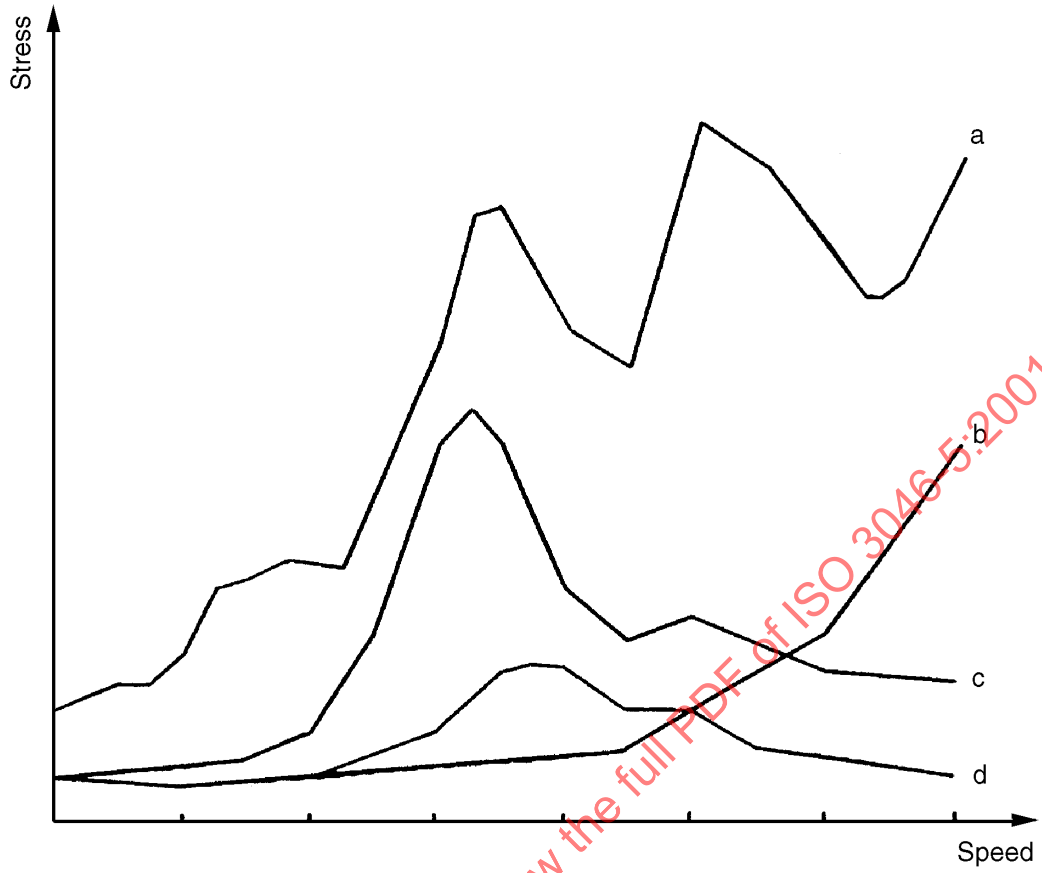
Figure 2 — Typical vector diagram



Key

a Mean torque
b Sum of harmonics
c Order N° 0,5 Harmonic N° 1
d Order N° 1,0 Harmonic N° 2
e Order N° 1,5 Harmonic N° 3
f Order N° 2,0 Harmonic N° 4
g Order N° 2,5 Harmonic N° 5
h Order N° 3,0 Harmonic N° 6
i Order N° 3,5 Harmonic N° 7
j Order N° 4,0 Harmonic N° 8

Figure 3 — Harmonic analysis of 4-stroke engine torque diagram



[a] Synthesized
[b] 3,5 Order
[c] 6 Order
[d] 5,5 Order

Figure 4 — Typical vibratory torsional stress

4 Calculation of torsional vibration

4.1 General

Knowing the dynamic characteristics of the shaft system, it is possible to calculate:

a) the natural frequency and modes;

b) the responses of the system to the excitations.

When previously agreed by the contract, the supplier of the set shall be responsible for the torsional vibration calculation using a conventional method agreed upon by the parties concerned and, where appropriate, the allowable calculation simplification.

4.2 Method used

4.2.1 Free vibrations

This is the calculation of eigen values (natural frequencies) and eigen vectors (natural vectors) of the linear equation system predicting the undamped shaft system.

4.2.2 Forced vibrations

This is the solution of differential equations with one side representing the engine excitation torque and, if necessary, those of the other components of the shaft system when their excitation torques cannot be neglected.

4.3 Calculation data

The data to be taken into account for the torsional vibration calculation of the shaft system are the polar moment of inertia, the torsional stiffness of each component, the excitation torque of components, the operating speed band, the specific operating parameters and, where appropriate, the data concerning the torsional vibration dampings (see 5.4).

The manufacturer of the engine(s) and of the driven machinery shall communicate all the relevant information on the equipment that they supply (e.g. the propeller) so that the torsional vibration calculations can be carried out by the set supplier.

4.4 Calculation results

The results obtained when using the methods mentioned in 4.2.1 and 4.2.2 can determine, amongst others, the following:

a) the natural frequencies, natural vectors and resonance speeds;

b) the torsional stresses in the shaft system;

c) the vibratory torques in elastic couplings and the other items influenced by these torques;

d) the vibratory amplitudes at given points of the shaft line;

e) the thermal power generated in couplings and the other damping sources.

The results can also be used, if necessary, to obtain the vibratory accelerations in gears.

4.5 Calculation report

If the contract requires a report to be made, of the torsional vibration calculation carried out, this shall be provided by the set supplier. It shall contain leading particulars of the RIC engine, configuration of the shaft system and calculation results in accordance with 4.4 as far as is necessary. If the set supplier has subcontracted the calculation then it shall be clearly stated in the report.

5 Measurement of torsional vibration

5.1 General

When it is specified in the contract, the measurement of the torsional vibrations of the shaft system shall be carried out by the set supplier to verify the calculation. The measurement and the designation of the measuring position shall be specified in the contract in order to assess the amplitudes at this position.