

Reciprocating internal combustion engines — Performance —

Part 5: Torsional vibrations

ICS 17.160; 27.020

National foreword

This British Standard reproduces verbatim ISO 3046-5:2001 and implements it as the UK national standard. It supersedes BS 5514-5:1979 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/14, Reciprocating Internal Combustion engines, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

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Summary of pages

This document comprises a front cover, an inside front cover, the ISO title page, page ii and iii, a blank page, pages 1 to 10, an inside back cover and a back cover.

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Amendments issued since publication

Amd. No.	Date	Comments

This British Standard, having been prepared under the direction of the Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 02 February 2001

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ISBN 0 580 38903 0

INTERNATIONAL STANDARD

ISO
3046-5

Second edition
2001-12-01

Reciprocating internal combustion engines — Performance —

Part 5: Torsional vibrations

Moteurs alternatifs à combustion interne — Performances —

Partie 5: Vibrations de torsion



Reference number
ISO 3046-5:2001(E)

Foreword

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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.

ISO 3046-5:2001(E)

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. 11/4 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.

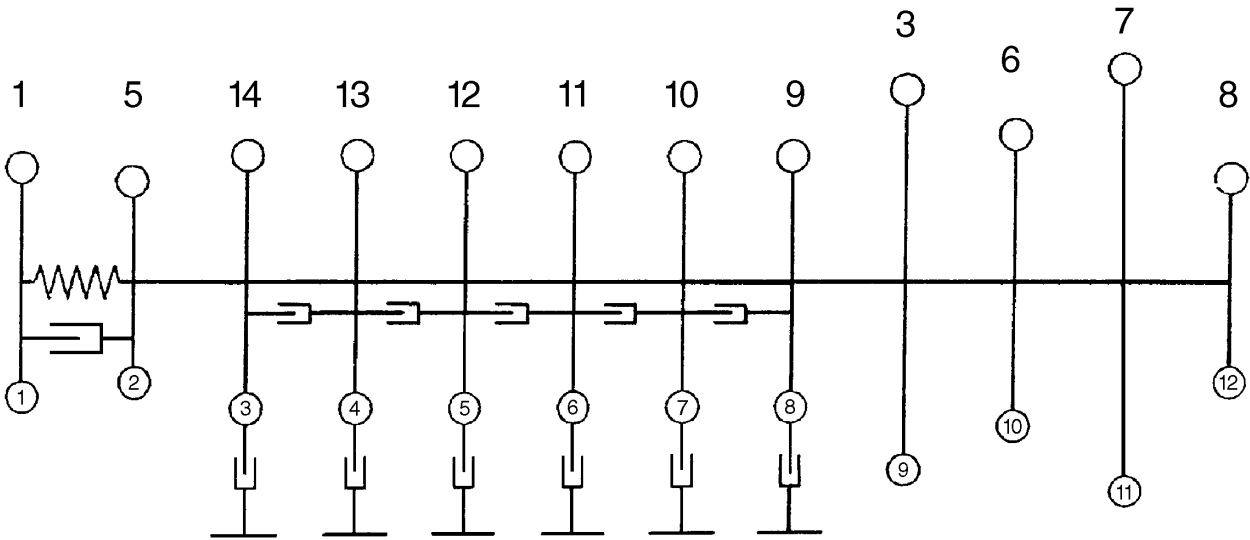
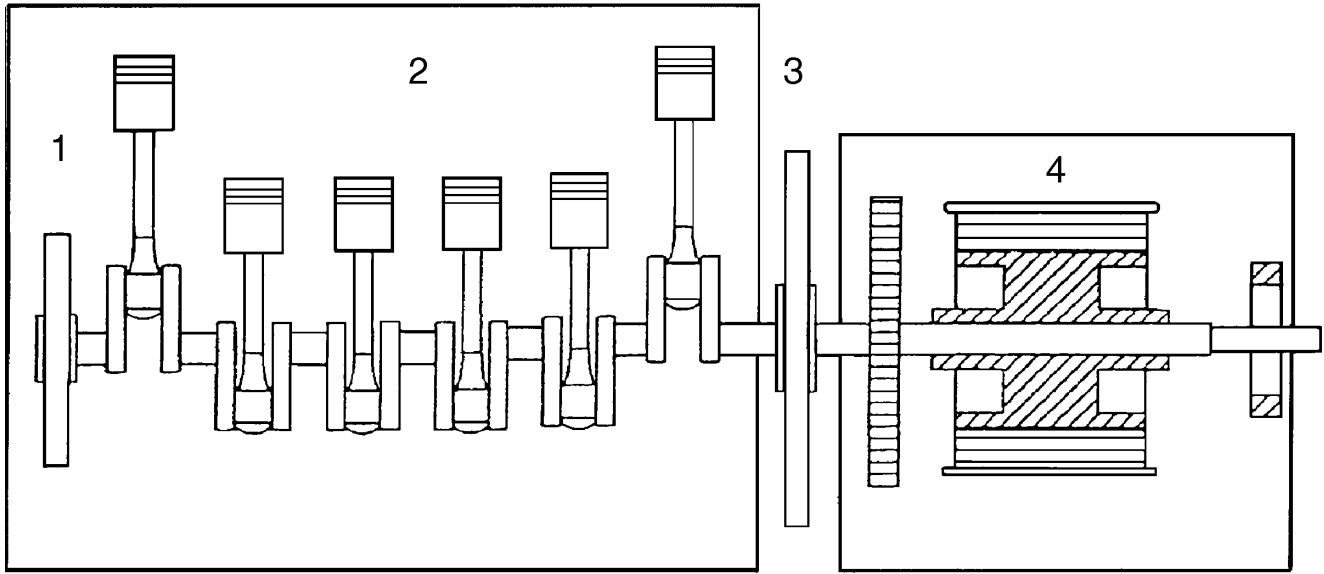
3.15**additional torsional stress**

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

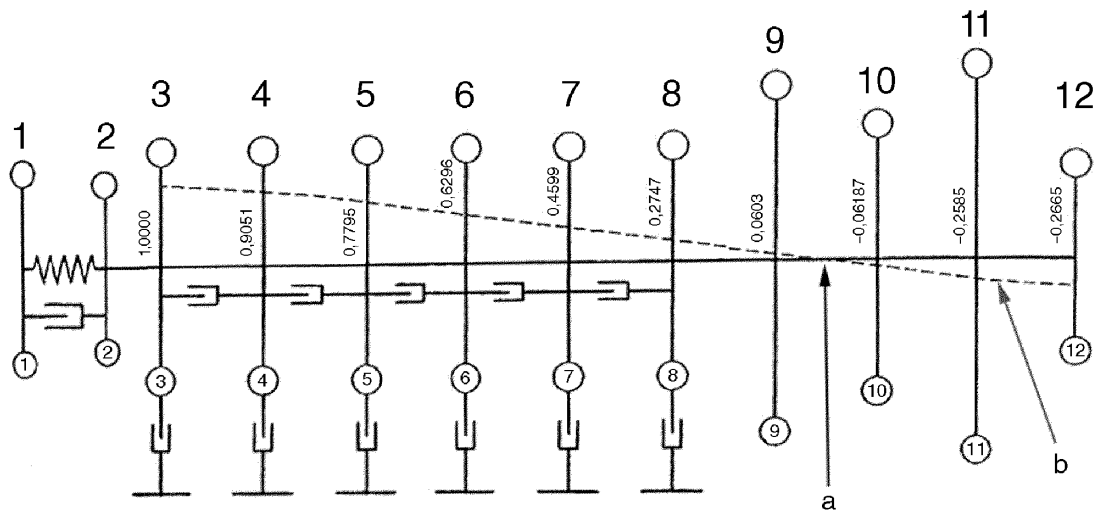
NOTE Continuous operation in this speed range is forbidden, but passing through in transient operation is permissible provided that it offers no danger or damage to the shaft system.



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

Figure 2 — Typical vector diagram

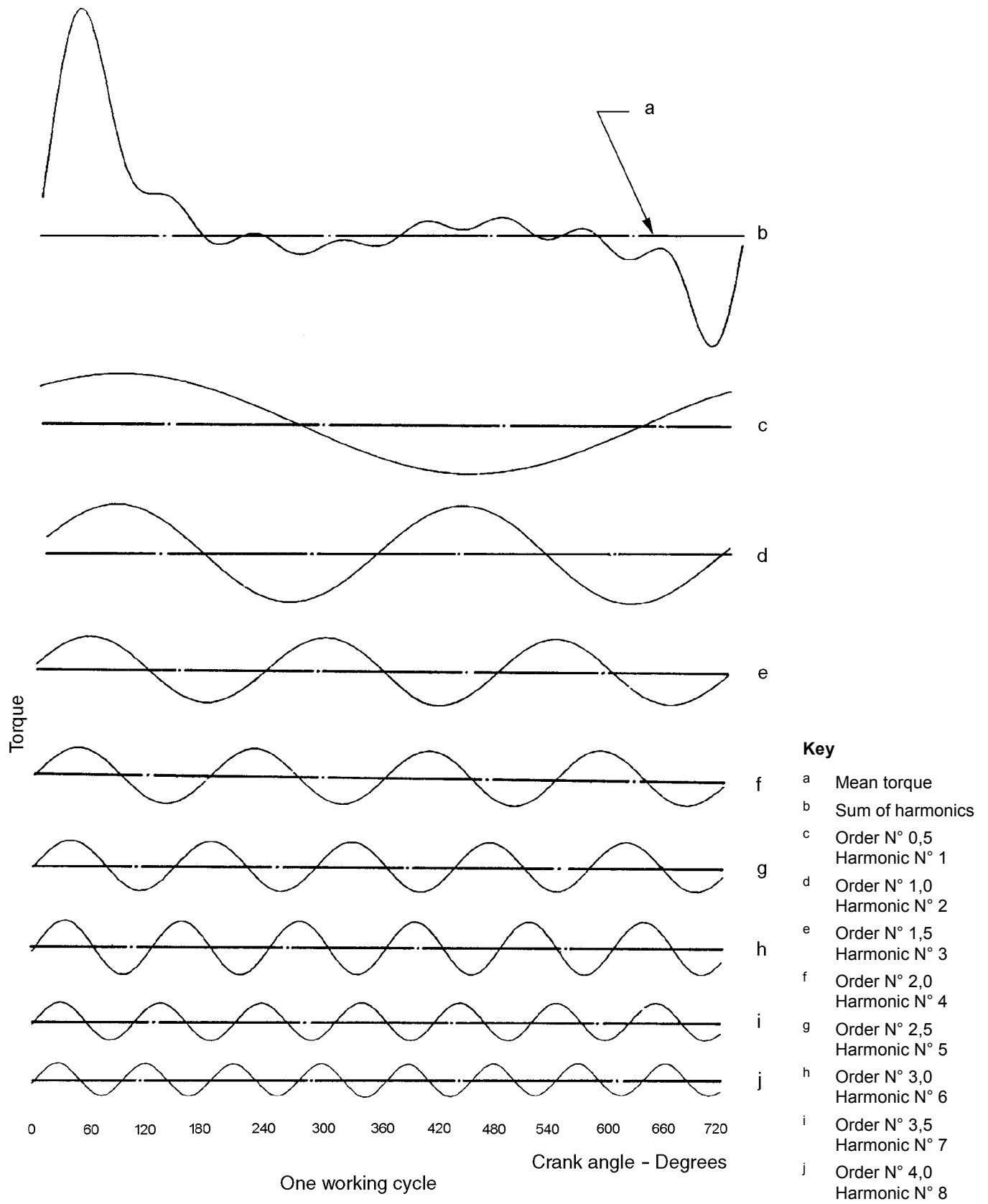


Figure 3 — Harmonic analysis of 4-stroke engine torque diagram

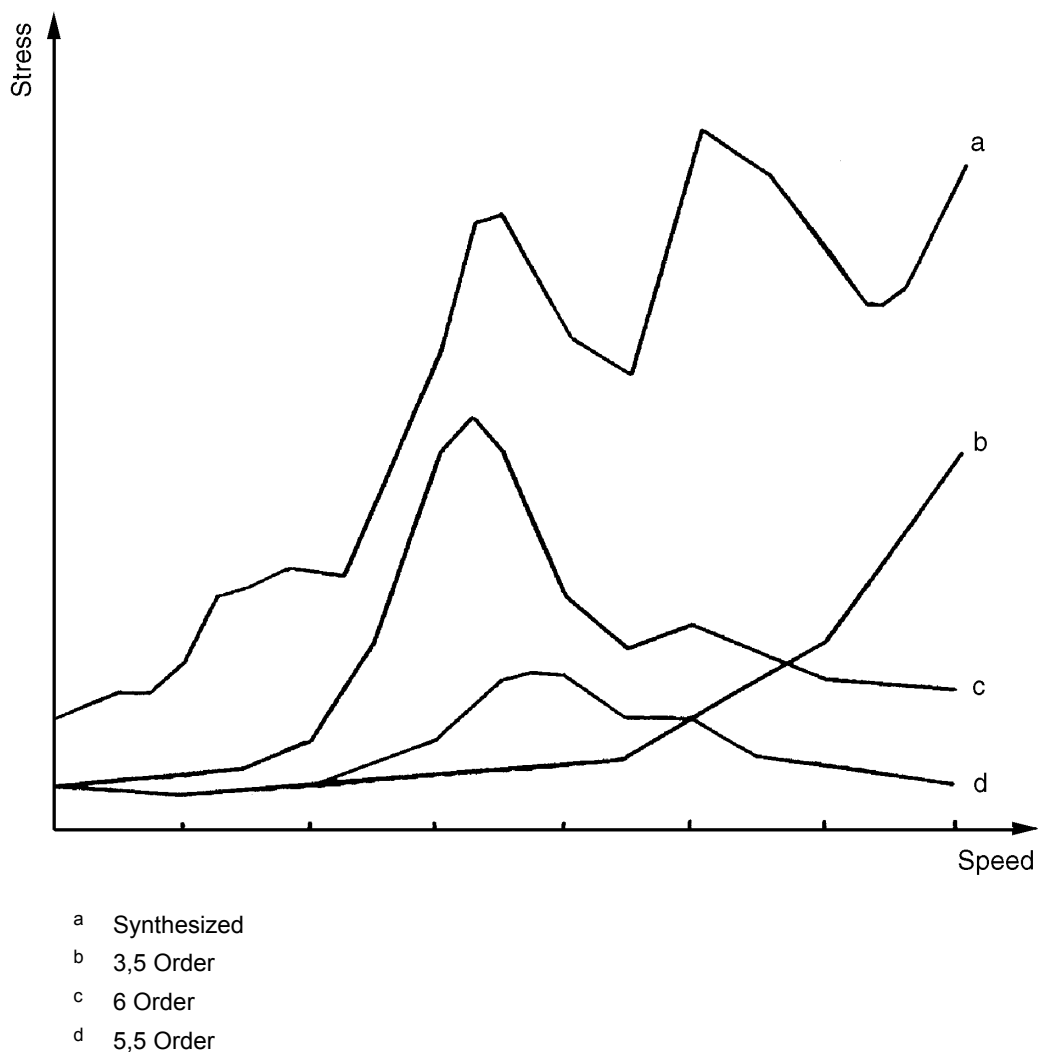


Figure 4 — Typical vibratory torsional stress

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.

5.2 Method of measurement

The following devices may be used as torsional vibration pick-up:

- a) eddy probe (non contacting);
- b) strain gauge;
- c) optical decoder.

Other methods can be used on agreement between the customer and set supplier.

5.3 Measured parameters

Depending upon the method of measurement, the following parameters shall be measured and recorded in the test report:

- a) rotational velocity of the shaft system;
- b) engine power;
- c) torsional vibration amplitude;
- d) strain;
- e) ambient temperature of test site;
- f) natural frequency and critical speed range.

Additional parameters that may influence the torsional vibration:

- g) firing order of the RIC engine cylinders.

Other parameters can be measured on agreement between the customer and set supplier.

5.4 Measurement test report

The torsional vibration measurement test report shall be provided by the set supplier if required by the contract. It shall contain leading particulars of the RIC engine, configuration of the shaft system, the measured parameters in accordance with 5.3 (as far as is necessary) and the test site. In addition, the type, accuracy and calibration method of the measuring equipment and the positions of the displacement sensors shall be recorded. If the set supplier has subcontracted the torsional vibration measurements then it shall be clearly stated in the test report.

When the measurement conditions differ from the conditions specified in the contract an agreement shall be made before commencement of the measurement, concerning the effect of the different conditions and the corrections that should be applied to the results.

If there is a big difference between the vibration amplitudes measured and those calculated, a re-evaluation of the calculation results shall be carried out using the values measured (see 4.3).

6 General requirements

6.1 Set supplier

The supplier of the set may be the engine manufacturer or the manufacturer of the driven machinery or a third contractor. If a purchaser buys an engine from one manufacturer and the driven machinery from another, the purchaser is regarded as the supplier of the set.

6.2 Guarantee

The guarantee that the set will operate satisfactorily from the torsional vibration point of view, may be given upon request by the supplier of the set only where installation and maintenance instructions for the set have been precisely followed.

6.3 Responsibility

6.3.1 Where torsional vibration calculations of the complete shaft system are requested, the supplier of the set shall be responsible for the calculation even if he subcontracts them.

6.3.2 Where additional verification of the torsional vibration of the complete shaft system is required, the supplier of the set shall be responsible for the measurements carried out even when he subcontracts them. In particular it is up to the supplier to choose, in agreement with the customer or the inspection organization which represents him, the methods of measurement to be used.

6.3.3 If there is a range of operating speeds for the set where the vibrations could cause damage, the supplier of the set shall, with the agreement of the other parties, take the necessary steps to eliminate the critical vibrations or to avoid these speed zones.

6.3.4 Any corrective actions, as far as necessary, to modify the shaft system are the responsibility of the set supplier and shall be agreed upon by the component manufacturers and the other parties.

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