
**Milling cutters for high speed machining —
Safety requirements**

Fraises pour usinage à grande vitesse — Prescriptions de sécurité

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

ISO 15641 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 29, *Small tools*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this standard, read "...this European Standard..." to mean "...this International Standard...".

Annexes A and B of this International Standard are for information only.

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Foreword

The text of EN ISO 15641:2001 has been prepared by Technical Committee CEN/TC 143 "Machine tools – Safety", the secretariat of which is held by SNV, in collaboration with Technical Committee ISO/TC 29 "Small tools".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2002, and conflicting national standards shall be withdrawn at the latest by March 2002.

The annexes A and B are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This standard is intended to assist designers, manufacturers and suppliers of milling cutters to satisfy their obligations in respect of high speed machining applications. It defines requirements for design, confirmation testing and information for use that manufacturers and suppliers are to provide.

The prime objective is to ensure that milling cutters, employed for high speed machining, will be able to safely withstand the quadratic increase in centrifugal force resulting from their application at increased rotational speed.

It is based upon a collaborative German research project established to investigate the suitability of milling cutters for use in high speed machining operations.

This standard deals only with the tool and is not sufficient alone to ensure the safety. The safety of machinery is dealt with by other specific safety standards.

This standard takes account of cutting conditions only by requiring the manufacturer to provide application information.

Informative annex A provides guidance for reduction of hazards by design and informative annex B explains the scope limits.

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1 Scope

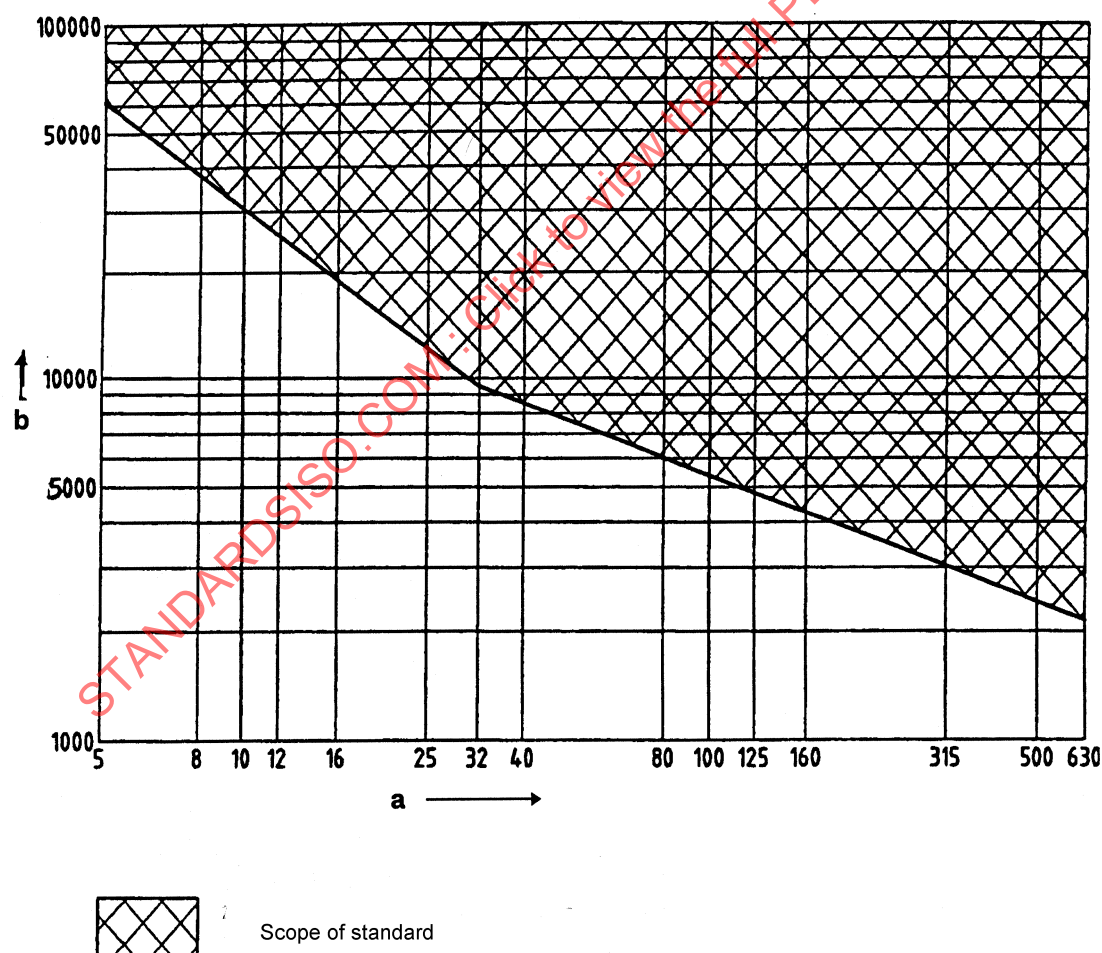
This standard deals with the principle hazards arising from use of milling cutters, e.g. milling cutters according to ISO 3855, used for high speed machining (chip removal machining at increased peripheral speeds) on metal working machine tools and prescribes safety requirements.

It specifies design methods, centrifugal force test procedures, operational limits and the provision of information that will lead to minimisation or elimination of these hazards.

The standard is applicable to milling cutters which are intended for operation at speeds in accordance with figures 1 and 2.

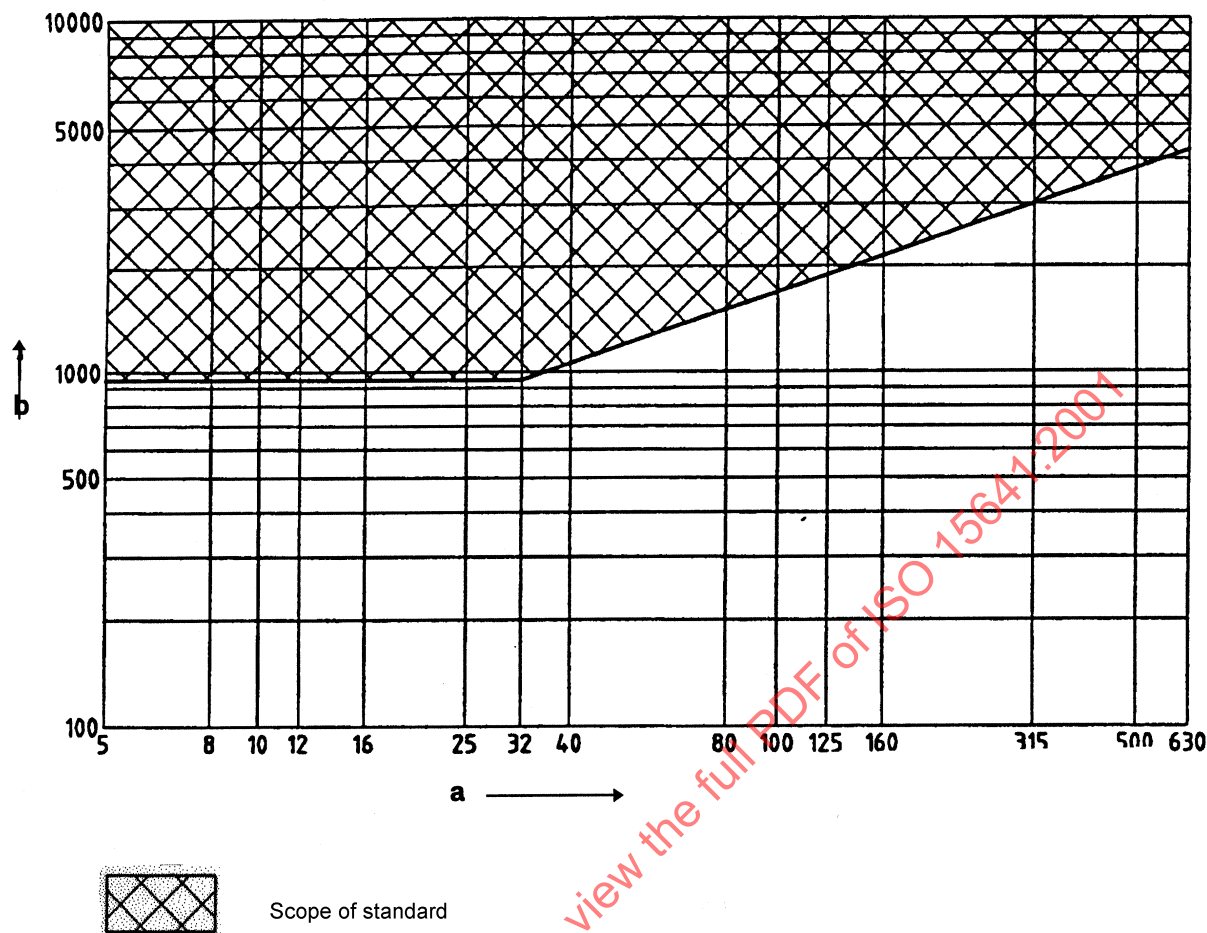
These figures respectively define the rotational speed limits and peripheral speed limits for specific cutter diameters.

NOTE A detailed explanation is provided in annex B.



- a Maximum diameter of tool D in mm
 b Rotational speed n in min^{-1}

Figure 1 - Rotational speed n vs maximum diameter of tool D



a Maximum diameter of tool D in mm

b Velocity at D (speed v_D at maximum diameter of tool D) in $\frac{\text{m}}{\text{min}}$

Figure 2 - Velocity at D (speed v_D) vs maximum diameter of tool D

2 Normative references

This European Standard incorporates by dated or undated reference provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1070

Safety of machinery – Terminology

ISO 1940-1:1986

Mechanical vibration – Balance quality requirements of rigid rotors – Part 1: Determination of permissible residual unbalance

ISO 3002-1

Basic quantities in cutting and grinding – Part 1: Geometry of the active part of cutting tools – General terms, reference systems, tool and working angles, chip breakers

ISO 3855

Milling cutters – Nomenclature

3 Terms and definitions

For the purposes of this standard the terms and definitions given in EN 1070, ISO 3002-1 and the following apply:

3.1 Tool classification terms

3.1.1

solid or one-piece cutter

milling cutter which has no detachable parts. Its body and cutting part or parts are one piece.

3.1.2

composite cutter

milling cutter in which the cutting part or parts (e.g. tips) are attached to the body by material bonding (e.g. by brazing).

3.1.3

complex cutter

milling cutter in which one or more parts (e.g. indexable inserts, cartridges, clamping elements) are attached to the body by mechanical fastening (e.g. key bolt, screw bolt or clamp bolt fixing which operate by friction lock or form lock principles).

3.2 Types of fixing

3.2.1

bonding

securing of cutter parts with material bonding such as brazing, welding or gluing.

3.2.2

separable

securing of cutter parts by detachable fastening(s). Examples are friction lock and form lock fixings, or a combination of these, which can be mounted and detached repeatedly.

3.2.3

friction lock

means of securing cutter parts where friction force prevents the movement of parts in use.

3.2.4

form lock

means of securing cutter parts where the shape and arrangement of parts prevents their movement in use.

3.3 Terms for the designation of geometric parameters

3.3.1

maximum diameter of tool D

maximum diameter of the circle created by cutter rotation. See D in figures 3, 4 and 5.

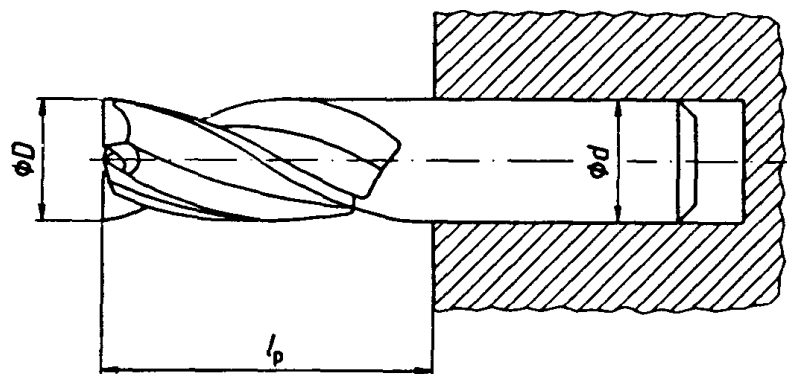


Figure 3 - Example for solid, one-piece or composite cutter

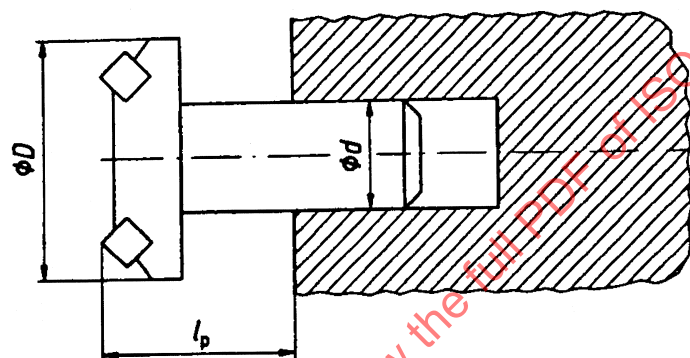


Figure 4 - Example for complex cutter

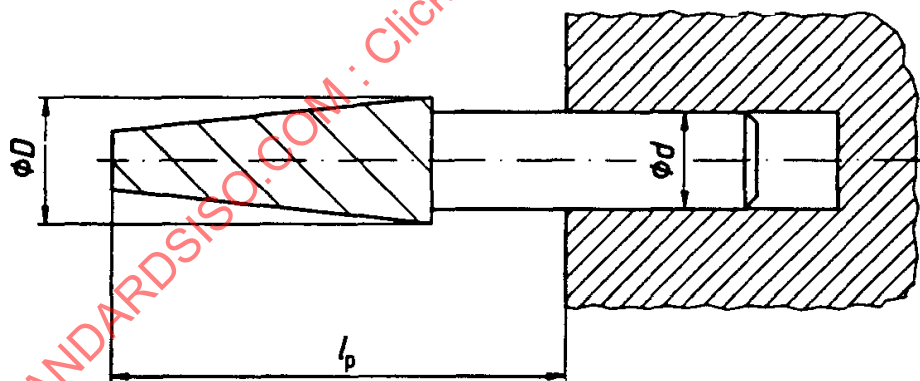


Figure 5 - Example for tapered solid, one-piece or composite cutter

3.3.2**critical diameter d for bending**

diameter exposed to greatest stress of bending due to centrifugal and cutting forces. See d in figures 3, 4 and 5.

3.3.3**protruding tool length l_p**

free accessible length of a mounted cutter measured along its axis of rotation. See l_p in figures 3, 4 and 5.

3.4 Terms for the designation of mechanical parameters**3.4.1****mass of milling cutter m_w**

mass of a completely mounted and ready-to-use milling cutter.

3.4.2**component masses m_i**

masses of component parts of a complex milling cutter.

3.5 Terms for the designation of load parameters**3.5.1****maximum rotational speed n_{max}**

maximum rotational speed indicated by the manufacturer for a specific milling cutter.

3.5.2**rotational speed for test**

speed determined by multiplying n_{max} by the rotational speed safety factor used for speed testing.

4 Hazards**4.1 Effects which generate hazards****4.1.1 Primary hazards**

When milling cutters are applied at high peripheral speeds, the forces associated with normal machining are exceeded by the squared increase in centrifugal force due to the high rotational speeds employed. Other forces, for example: through the acceleration of the cutter to working speed, clamping at the drive end, prestressing forces in complex cutters and fluid forces from air or cooling liquids have also to be considered. The centrifugal force will usually be the primary load and the high levels of energy applied leads to high structural loads which can, in the extreme, burst the cutter.

High levels of rotational energy are contained within milling cutters when they are applied at high peripheral cutting speed. In the event of cutter failure, this energy is likely to be released. The released component masses will move, in the rotational or translatory directions, away from their original axis of rotation at high velocities and with unpredictable trajectories. Their energies can only be dissipated through single or multiple collisions or deformation of machine parts in their motion paths.

Dependant upon the mode of cutter failure, the released energy can be sufficient to destroy and penetrate machine parts. This may lead to serious injury of persons at or near the machine. It is inconceivable that operating personnel will be able to stop the machine or to leave the danger zone, in time to avoid such injury, because of the dynamics of these high speed machining operations.

4.1.2 Handling hazards

Hazards for operating personnel also arise from the handling of milling cutters as may be necessary both before and after their use in machining operations (e.g. transport, assembly, mounting/dismounting, clamping at the machine spindle) (see clause 7).

4.2 Modes of cutter failure

Failure of milling cutters, used at high peripheral speeds, can be attributed to the following fundamental causes:

4.2.1 Body failure

Deformation or bursting of the milling cutter body as a result of structural overload. This can result from:

- Long protruding cutters which fail due to cutting forces, centrifugal forces or by unbalance. The mounting of such long protruding cutters is critical since the introduction of eccentricity can lead to failure at substantially reduced rotational speed due to out-of-balance forces.
- Short protruding cutters which fail when stresses due to the centrifugal force exceed the ultimate strength of the cutter body material.

4.2.2 Failure of cutting element fixing

In complex cutters the connection between the body and the cutting element (e.g. indexable insert or cartridge) fails due to centrifugal and/or cutting forces causing structural overload (e. g. by deformation or fracture).

4.2.3 Failure of cutting element

Structural overload of the cutting element due to centrifugal and/or cutting forces.

5 Safety requirements and/or measures

5.1 Providing safety by design

Milling cutters, intended for application at high peripheral speeds, shall be designed such that they can withstand the centrifugal forces generated in use. The rotational speed safety factor shall be two (2) which provides a four to one (4 : 1) centrifugal force safety factor or 1,6 in accordance with the requirements of 5.4.3.

As far as tools with geometrical similarity within product lines are concerned, calculation is permissible if the results are sufficiently assured by centrifugal force type testing of at least one tool from that product line.

Verification: By calculation and/or centrifugal force type testing.

5.2 Importance of balance

Out-of-balance forces due to eccentricity increase quadratically with increase in rotational speed.

For safety reasons a milling cutter shall have a balance quality grade equal or better than G 40 in accordance with ISO 1940-1 : 1986 at the maximum rotational speed $n_{\max}$ (see 3.5.1).

If, for performance (e.g. improved tool life or machined finish), a lower value (e.g. G 6.3, G 2.5) is needed, this is also acceptable for safety.

The graph in figure 6 for the permissible specific residual unbalance U_G^* is based on the following formula and has been extended for higher speed level:

$$U_G^* = 3,8197 \cdot 10^5 \cdot \frac{1}{n_{\max}^5} \quad (\text{see annex of ISO 1940-1 : 1986})$$

where

– $n_{\max}$ is the maximum rotational speed in min^{-1}

– U_G^* is the permissible specific residual unbalance for milling cutters in $\frac{\text{g} \cdot \text{mm}}{\text{kg}}$ = permissible residual mass centre displacement in μm

Verification: Measuring of milling cutter unbalance.

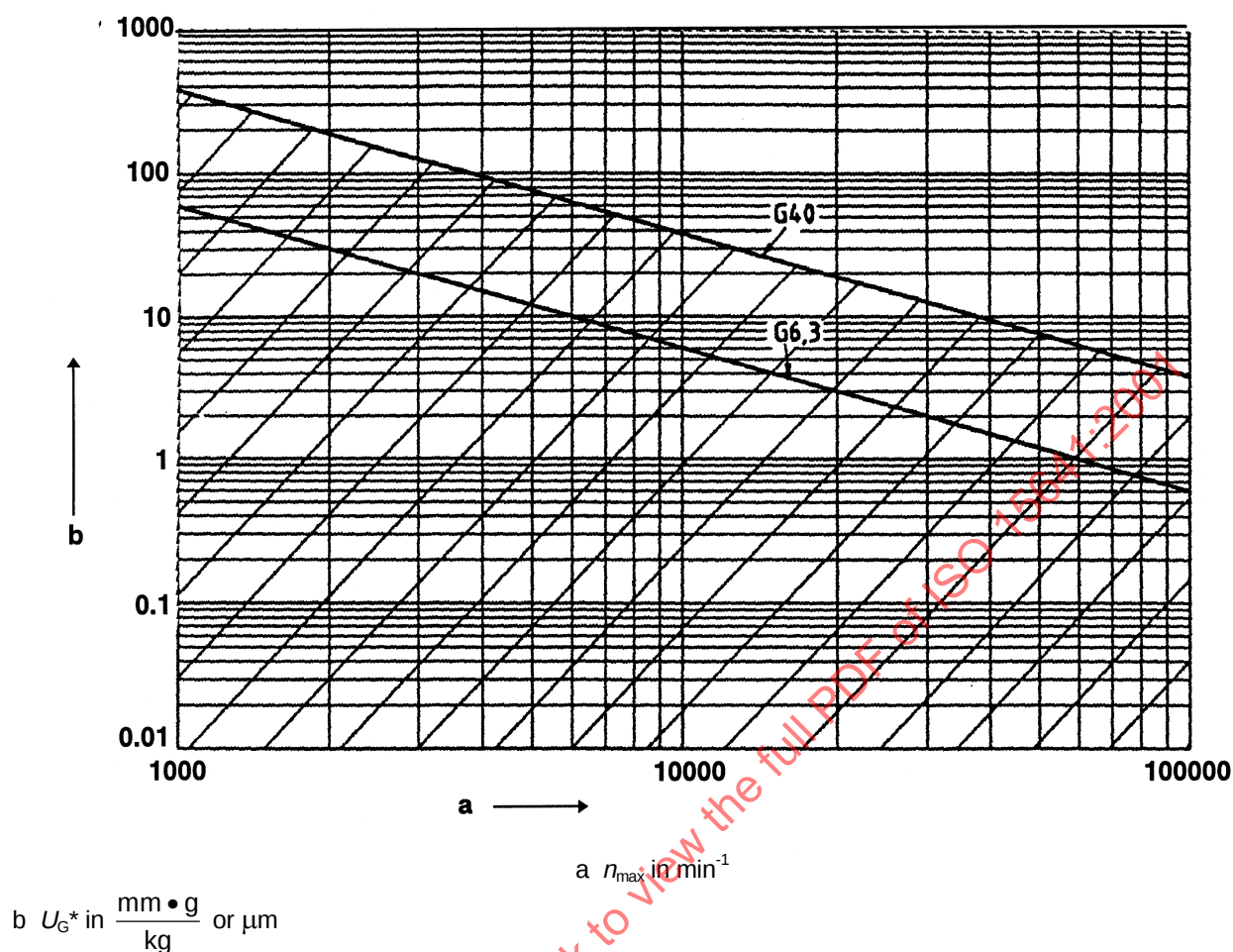


Figure 6 - Permissible specific residual unbalance for balance quality grades G 6.3 and G 40

5.3 Integrity of manufacturing

To ensure that milling cutters intended for use at high peripheral speeds can be safely applied their manufacturing shall be of consistent quality and free from physical defects caused by heat treatment or other cracks.

Verification: Manufacturer's quality procedures.

5.4 Centrifugal force type testing

5.4.1 General requirements

To ensure that milling cutters intended for high speed machining can be safely applied, centrifugal force type testing shall be performed for each cutter design type.

This type testing also includes:

- Verification of conformance with design drawings and, if necessary design calculations and
- Visual inspection, measurement and checking of the assembled condition of the milling cutter.

5.4.2 Testing of solid, one-piece or composite cutters

Solid, one-piece or composite cutters shall be subjected to centrifugal type testing at twice their declared maximum rotational speed without bursting or fracture occurring.

5.4.3 Testing of complex cutters

Complex cutters may be tested in accordance with 5.4.2 but sufficient assurance of resistance to centrifugal force is also demonstrated when a rotational speed for test of 1,6 times the declared maximum rotational speed is reached without bursting or fracture and any permanent deformation or displacement does not exceed 0,05 mm.

5.4.4 Duration of rotational speed for test

The rotational speed for test applied in accordance with 5.4.2 or 5.4.3 shall be sustained for a minimum duration of one minute.

6 Marking of milling cutters

Milling cutters intended for high speed machining shall be clearly, visibly and permanently marked with the following minimum data:

- the maximum rotational speed

and, if possible, with the following minimum data:

- name or trademark of the manufacturer or supplier
- specific code which, in conjunction with the manufacturer's accompanying documentation, enables cutter characteristics to be determined

Verification: Visual inspection of the cutter and examination of the relevant drawings and documentation.

7 Documentation and information for use

The manufacturer shall provide documentation to accompany the cutter. This shall contain or give reference to information for the safe application of the cutter. This information shall include, as a minimum:

- specification of the maximum rotational speed for the cutter $n_{\max}$
- confirmation of the type-test
- specific instructions for correct assembly and dismantling of all component parts
- decoding of the marking on the cutter in clear text
- information for repair and maintenance of the cutter with particular reference to spare parts and parts subject to wear
- information to determine the maximum permitted protruding length for the cutter l_p (see 3.3.3)
- information as to the condition of balance of the cutter
- information as to the correct manner of milling cutter application (is particularly important for safety in high speed machining)
- information for applicable cutting and other exchangeable parts
- information for correct clamping of the tool.

The manufacturer or supplier shall declare in the information for use or sales literature whether the milling cutters have been manufactured in accordance with this standard.