ACTA MECHATRONICA

2022 Volume 7 Issue 2

International Scientific Journal about Mechatronics

electronic journal
ISSN 2453-7306

CONTENTS

(JUNE 2022)

doi:10.22306/am.v7i2.85

Received: 21 Feb. 2022
Revised: 09 Apr. 2022
Accepted: 20 Apr. 2022

Application of Geometric Product Specifications on gearbox component drawings

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Keywords: geometrical product specifications, gearbox, drawing.
Abstract: Technical documentation of individual gearbox components is an important part of the production process. For the development and production of these components, an improved engineering tool is used to specify and verify the geometry of the workpiece - Geometrical Product Specifications (GPS) system. This system is intended only for checking geometry and is based on computational mathematics and correct, consistent logic using general sets of rules. This paper is devoted to the application of geometric tolerances used in drawings to components of gearboxes, such as gearbox bodies, shafts, covers, and gears.

1 Introduction

Gear mechanisms are used to transmit torque from input shaft to the output shaft. This transmit is carried out by gear wheels where the commonly used type is spur gearing. Gearing is used in a gear train which composes of series of gear wheels mounted on shafts and these are mounted on bearings. These components placed in a closed box represents basic concept of gearbox, ensuring the fluent transmission of power [1]. Gear wheel as a main part of gear train falls under condition of quality. This condition can be defined by more factors such as material, geometric design, quality of manufacture. Upon mentioned factors the quality of manufacture is the important one as the manufactured geometric dimensions should follow the theoretical ones as much as possible. This on the other hand can save investment in material used and maintenance. Design of gear wheel is defined by basic parameters such as modulus, pressure angle etc. but also by possible corrections and modifications of profile, clearances and tolerances.

Must know parameters for proper design need to be functional requirements, which are then followed by technical specifications. The design of gear wheel can begin in a way of creating solutions either by hand or by using CAD software [2-3]. Creation of drawings with CAD software is faster and more precise as well (Fig. 1).

Such software is also used for FEM simulations and mathematical models, used to check the mechanical properties of designed geometry [4]. With the given premisses of guaranteed mechanical properties, it is advantageous to modify the part in a way where the manufacturing process will be easier. All modifications, dimensions and tolerances are given on the technical drawing of such part, where this drawing has to be precise, clear to read and creation wise it is advantageous to create it in the fastest way possible, which using nowadays CAD software support [5].

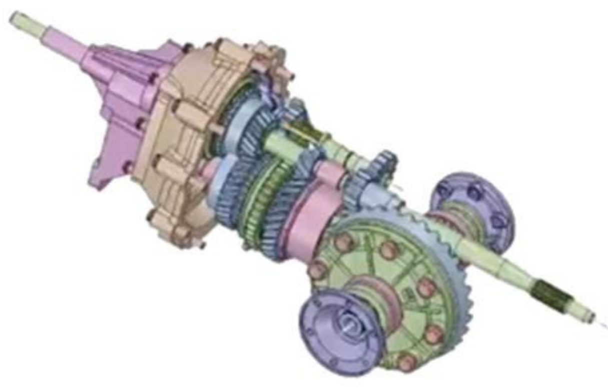

Figure 1 CAD gearbox

Fails, shortcomings or improper drawing documentation often leads to delays in manufacturing process. One set of shortcomings is done by designers, another may be done by prescriptions. This is avoided by using standards, national or international. These standards regarding the technical drawings prescribe the symbols and methodology used. Propper technical drawing prescribes requirements for a functional design, where it is necessary to use clear and relevant information for product manufacture and verification [6-8].

Result of a production process is a part which has some differences from the theoretical one in a form of dimensional or geometric deviations. These are the differences between the real values to the nominal ones measured by technicians to check the accuracy of production process [9-11]. To avoid any mistakes or errors, a system was developed for any stage of the manufacture process. The system is called geometrical product specification (GPS), which defines the geometry in a form of shape, dimensions and surface characteristics, where all of these specifications are used on technical drawing.

2 Geometrical Product Specification - GPS

For specification and verification of the geometry of the workpiece is advantageous to use an integrated GPS system. This sysyem is an enhanced tool used by engineers and designers during development and production process as well. In an international enviroment it is common to outsuorce some actibities in a form of new technologies, munufacturing processes, materials and products, therefore adoption of GPS has quite signigicant impact. Main aim of integrated GPS system is to allow and make possible to management from vost efficiency point of view. Altough it is not used for creation of variability in products and processes. [12]. The GPS in its nature improves currently used approach, and unites other systems such as International Standards Organisation (ISO) and Technical Commissions (TCs).

The idea is to use this product for the control and datavmanagement of material and geometric properties tied to the workpiece or its components. GPS is ussd only for controlling the geometry, where future development is rebolved around computational mathematics and consistent logic following general rule sets applicable to any specification [13-16].

The major and most significant specification is to simplify and reduce cost for workpiece or final product, where the GPS can be utilized in every aspect. Furthermore, there are a variety of abbreviations to cover frequently recurring workpiece functions, such as notation for kinematic pairs.

2.1 Dimensioning

Engineering tolerances are defined and communicated using the Geometric Dimensioning and Tolerancing (GD&T) approach. It is a collection of guidelines created especially for designing and quoting, enabling the designer's intent to be communicated into all phases of the product cycle and ensuring the part is accurately interpreted. In the drawing documentation, GD&T uses markers and computer-aided three-dimensional solid models to explicitly define the basic geometry and its allowed deviations.

Establishing the base of a component element or assembly group is the fundamental concept of GD&T. Of course, this refers to the precise location and connections between elements. For the purpose of dimensioning and the application of tolerances or tolerance zones, the bases are chosen as the starting points. Functional bases must be chosen and are only one of the component's elements that determine the component's real placement in the manufactured assembly (product).

2.2 Tolerancing

In addition to dimensional tolerances, geometric tolerances are used to ensure more accurate product characteristics and forms. Geometric tolerances are set by the functional requirements of the product and the functional surfaces of the product. They are only utilized when a profile or shape has a defined functions and inaccuracies could compromise how well it performs.

The standards for product geometric tolerancing are defined in Standard ISO 1101, which also offers basic information of these tolerances. The following categories contain geometric tolerances:

- form tolerance (reference not needed),
- orientation tolerance (reference needed),
- position tolerance (reference needed),
- runout tolerance (reference needed).

The principle of the surface model between nominal features, specification features, and verification features is explained in more detail in Standard ISO 22432:2011. The ISO 25378:2011 standard has additional aspects, including geometric requirements, properties, and conditions. Each and every GPS defines the necessary geometric conditions and properties.

The deviation of a workpiece feature from the theoretically exact (ideal) geometry, orientation, or location is determined by geometric tolerances.

3 GPS uses in technical drawings

Most gears are made up of both non-standard and regular parts. Drawing documentation must be created for every non-standard gearbox component in order to be used in both the component's manufacture and inspection processes. The designs must also include other information, such as the description of tolerances, in addition to the shape and measurements. When utilizing CAD software to create drawing documentation, these geometric specifications can either be defined manually or in the program's library.

3.1 Assemblability of components

It means that the geometric tolerance of the dimensional elements and their associated features can be raised without affecting the parts' capacity to be assembled when the actual dimensions of the parts to be joined do not exceed the maximum dimension of the material. Figure 2 illustrates typical scenarios that could happen when a pin is inserted in a gear case bore.

Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 7 2022 Issue: 2 Pages: 13-17 ISSN 2453-7306

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For some functional applications, the position tolerances (position, concentricity, and symmetry) are insufficient to guarantee functionality. These functional requirements are shown on the drawing in further detail by the estimated tolerance zone. The defined tolerance zone for the toleranced feature is expanded in the direction of the facing (related) counterpart according to this notation.

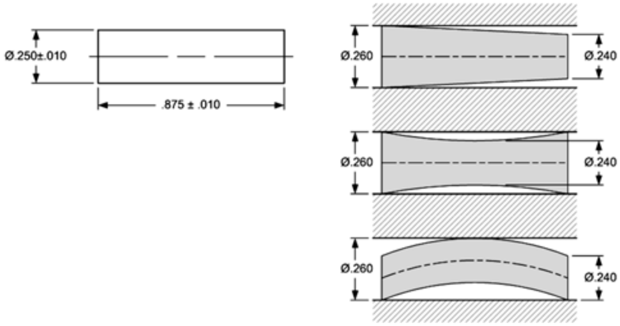

Figure 2 Fitting hole with a pin

After the numerical tolerance value in the tolerance box, the need for an offset tolerance zone is indicated by the letter P in a circle. The position of the element should be coded, the P in the circle should be entered before the numerical value of the dimension, and the outline of the displaced toleranced element (pin, bolt, pin, etc.) should be marked with a thin dotted line with two dots.

A surface produced by two parallel planes or a single element (such as the surface of a cylinder) may both be subject to the envelope inspection criterion (e.g., a groove). A mark E in a circle put after the tolerance of the associated length dimension specifies the envelope condition on the drawing.

The requirement of the enveloping area condition guarantees that, despite the relevance of the independence of dimensions and geometry, no part of a cylindrical feature or of an element formed by two parallel planes can exceed the enveloping area of the correct geometrical parameters with a dimension at the maximum limit of the material (by the entry of the E mark in the circle and the entry TOLERATION ISO 8015).

For illustration, the criterion of the enveloping area of the cylindrical shaft given in the drawing of the feature is determined for features of the character of the shaft, which is one of the main elements of the gearbox:

- that the entire toleranced element (such as a cylindrical shaft) must fit inside the boundaries of the appropriate geometric shape, with dimensions that are equal to the toleranced element's upper limit dimension;
- that the tolerance zone for each real local shaft dimension must be met

3.2 Tolerances of position

The shape tolerances of the geometric elements of the base itself are not defined by the position tolerances, which are set by the geometric elements connected to the base. It should be remembered that the position tolerances cover both the feature's orientation and form tolerances.

Position, concentricity, and symmetry are all types of position tolerances. On production drawings of the lids, and also on drawings of the top and bottom pieces of the gear case, position tolerances are applied.

An illustration of the tolerance for the axis placement in relation to the system created by the three planes is shown in Fig. 3. It serves as an illustration of how tolerating the location of the gearbox mounting flange hole, which is used to secure the gearbox to the frame's base, is done. The cylinder or diameter t, with the tolerance value prefixed by the mark, defines the tolerance zone. The theoretically accurate dimensions with regard to the bases C, A, and B define the axis. The extracted (derived) axes in the illustration should be in a cylindrical zone including an axis diameter of 0.08 mm, which corresponds to the hole's theoretically accurate placement in relation to the base produced by planes C, A, B.

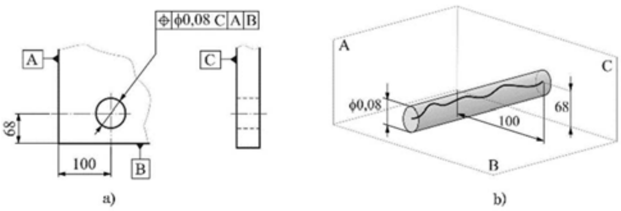

Figure 3 Example of tolerance of position: a) drawing example b) tolerance zone

3.3 Tolerance of form

Based on the ratio of the distance between the imperfections (deviations, waves, cracks, etc.) and their depth, surfaces or profiles' irregularity can be classified as form, waviness, or roughness. Form deviation, also known as the maximum permitted distance between points on the actual surface and the envelope surface, is the amount by which the workpiece's actual shape deviates from its nominal planned shape as shown on the drawing.

The cylindricity tolerance establishes the upper and lower limits of the straightness deviation, the axis deviation, the roundness deviation of the cylinder cross-sections, and the parallelism deviation of the opposing forming lines of the elements. Two cylinders that are equally spaced apart define the tolerance zone. On production designs of shafts and drawings of gear case bodies, the cylindricity tolerance is applied to match the cylindricity of holes.

3.4 Tolerance of runout

Runout, in general, describes workpiece surfaces that are rotationally symmetrical and their variations from a theoretically precise circular shape. The tolerance of the complete circular runout is used on gear shaft production designs. The zones for the various cuts are strongly related in terms of position and share the same base zero point, which defines total runout tolerance.

In the tolerance box, a mark with two arrows indicates the total runout (Fig. 4). The zone is the area enclosed by two concentric cylinders with axes parallel to the basic system's dotted axis and radii that deviate by a specified tolerance value. Axial runout is additionally utilized in addition to radial runout.

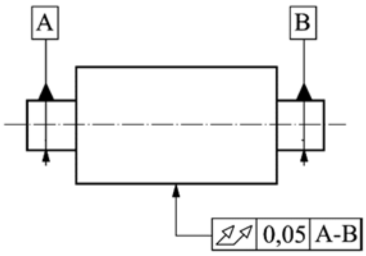

Figure 4 Example of total runout

3.5 Example of tolerance for gearbox

The dimensioning method for individual tolerances on the shaft's manufacturing drawing will be demonstrated using the example of shaft dimensioning.

The recommended tolerances for each of the distinct functional dimensions are shown in Fig. 5, and they are chosen as follows. The prescription for the cylindricity tolerance is under position number 1; its value is "10 µm = 0.01 mm" and is derived from the norm for the nominal dimension Ø63m6.

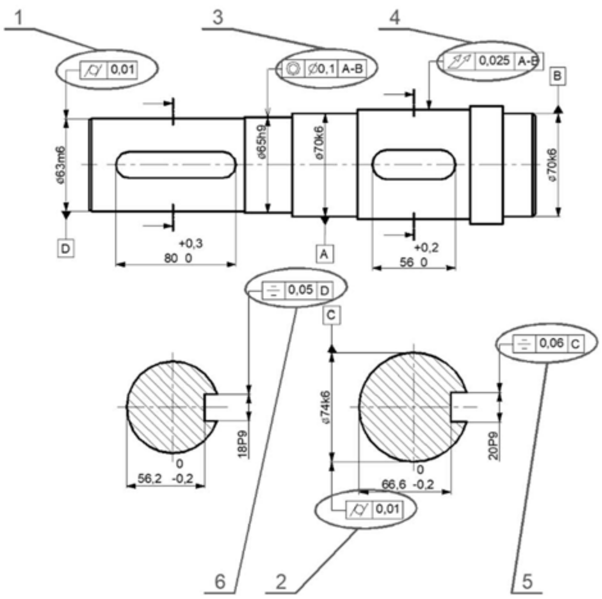

Figure 5 Technical drawing of a shaft

The cylindricity tolerance is listed at position number 2. According to the standard for the nominal dimension Ø74k6 (nominal dimension range from 50 mm to 120 mm) and accuracy grade 6, the value of the cylindricity tolerance is "10 µm = 0.01 mm".

The tolerance for concentricity is displayed under position number 3. The diameter of the rotating surface being addressed is Ø65h9, and accuracy grade 9 is used to calculate the value of the concentricity tolerance, which is "100 µm = 0.1 mm" for the nominal dimension.

Under position number 4, a prescription for a total circumferential runout tolerance example is provided. For the nominal dimension, or for the diameter of the rotating surface under consideration (Ø74k6) and accuracy grade 6, the tolerance value of the total circumferential runout is "25 µm = 0.025 mm".

Positions 5 and 6 are an illustration of a symmetry tolerance requirement. In the first instance, the nominal dimension of the groove width for the key 20P9 was used to calculate the value of the symmetry tolerance, which is "60 µm = 0.06 mm". In the second instance, the nominal dimension, or the dimension between the faces comprising the element 18P9, is used to calculate the value of the symmetry tolerance, which is "50 µm = 0.05 mm".

4 Conclusions

Application of GPS principles follow a few base rules which are applicable for non-standardised machine parts. This means that every dimension needs to have a tolerance field, which is given by the fact that every feature can have a small variation. Tolerances can be written either as a lower and upper tolerance for each dimension or by a block for a tolerance groups. Basic dimensions are aften times tolerance by the means of tolerance boxes, but only exceptions are for min - max dimensions semi-finished products or base points.

Tolerancing and dimensioning have a condition to fully define nominal geometry and tolerances. Technical drawings specify the specifications for completed (finished) components. Each dimension and tolerance that characterize the completed product must be shown on the drawing. Additional dimensions may be designated as reference ones if they are desired but not essential. Elements should have dimensions assigned to them, and they should be ordered to reflect the role of each element. Avoid giving descriptions of production procedures. It is best to discuss the geometry without mentioning the manufacturing process specifically. A dimension should be designated as informative if it is necessary throughout the manufacturing process but not in the finished geometry (due to dilatation or other factors).

All dimensions and tolerances should be positioned at the dimension and extension lines and at the appropriate elements for optimum clarity. When checking geometry using limit gauges or marked codes (such as blank material codes), it is customary to put the limit gauge or code in brackets or below the dimension. Unless otherwise specified, all dimensions and tolerances are applicable for 20 °C. The term "dimensions and tolerances" refers to the element's total length, width, and depth.

Acknowledgement
This work is a part of these projects KEGA 029TUKE-4/2021 "Implementation of modern educational approaches in the design of transmission mechanisms" and 027TUKE-4/2020 "Implementation of new practices and educational methods in optical methods of experimental mechanics to improve the educational level and practical skills of graduates of the Applied Mechanics and Mechanical Engineering study programs".

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Review process
Single-blind peer review process.

JOURNAL STATEMENT

Journal name:	**Acta Mechatronica**
Abbreviated key title:	Acta Mechatron
Journal title initials:	AM
Journal doi:	10.22306/am
ISSN:	2453-7306
Start year:	2016
The first publishing:	March 2016
Issue publishing:	Quarterly
Publishing form:	On-line electronic publishing
Availability of articles:	Open Access Journal
Journal license:	CC BY-NC
Publication ethics:	COPE, ELSEVIER Publishing Ethics
Plagiarism check:	Worldwide originality control system
Peer review process:	Single-blind review at least two reviewers
Language:	English
Journal e-mail:	**info@actamechatronica.eu**

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Publisher:	**4S go, s.r.o.**
Address:	Semsa 24, 044 21 Semsa, Slovak Republic, EU
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