GEOMETRIC TOLERANCES APPLIED TO GEARBOX SHAFT DRAWINGS

[a]SILVIA MALÁKOVÁ

Faculty of Mechanical Engineering, Technical University of Košice, Letná 9, 042 00, Košice, Slovakia
email: [a]silvia.malakova@tuke.sk

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Abstract: Gearboxes are among the most widely used transmissions. Technical documentation is used in all phases of the gearbox life cycle, which defines it and describes the processes taking place in it. The definition and correct prescription of the shape (geometry), and dimensions in the production drawing have an important role. This regulation ensures the optimal function of the component together with the scattering around the optimum, which also ensures a satisfactory function. All this is defined by the geometric specifications of the product. The paper deals with the application of these rules to the drawing documentation of gearbox shafts.

Keywords: standardization, geometric dimensioning, gearboxes tolerances, shafts.

1 Introduction

Today, gearboxes are an integral part of many machines. Mechanical gear transmissions generate a join between the drive and driven shafts and serve to transmit power and rotary motion. During transmission, the direction of rotation of the driven shaft, torque, circumferential or angular speed can change [1-3]. The mechanical transmission consists of at least two wheels connected to the shafts and the motion is transmitted from the drive shaft to the driven one [4-6]. Gears are, in practice, the most common type of gear mechanism and are used in a variety of forms.

Gears are used to transfer rotary motion and mechanical energy from one shaft to another [7, 8]. When the two gears mesh, i.e. in the gears, the tooth of one wheel fits into the tooth gap of the other wheel. The meshing wheel teeth touch each other with their sides and transmit the circumferential force from the drive wheel to the driven wheel by the pressure of the tooth on the tooth. The properties of the gear wheels have a significant effect on the functionality of the whole gear transmission mechanism. Gear transmissions are composed of non-standardized and standardized elements (Fig. 1).

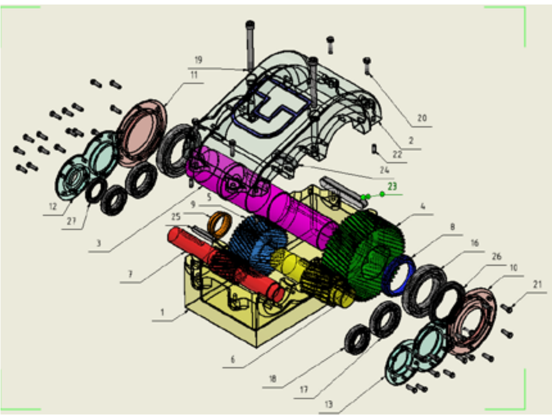

Figure 1. Elements of the gearbox.

Non-standard elements include gear wheels, shafts, covers, spacer and distance rings, and the bottom and top cover of the gearbox. Standardized elements include bearings, bolts, nuts, washers, seals, circlips, and seals.

The gearbox design process begins with a list of functional requirements and continues with the technical specifications for each gearbox element. The requirements arising from the manufacturing processes themselves affect the procedures for evaluating the geometry of the product [9-12]. The difficult economic situation and fluctuating demand greatly affect the designer's performance, which is reflected in significant speed, accuracy, and flexibility. The current designer uses a CAD system, finite element method (FEA), and mathematical modeling to meet design requirements and product specifications. The result of his work is the creation of technical documentation for individual non-standardized gearbox components [13-18]. When creating it, he follows the rules of technical drawing.

The technical drawing is an important means of exchanging information and communicating with technical experts around the world. Its knowledge is essential for reading and creating technical documentation. The technical drawing is a tool used in product development, production, distribution, use, maintenance, repair, and disposal [19,20]. It is used in the description of technical processes and production technologies, in instructions for use and maintenance, and in various documents of a technical character.

In recent years, technical drawing has become a global problem as the exchange of technical information around the world continues to intensify [21-24]. The rules of technical drawing defined in the ISO standards create a universal, globally comprehensible means of communication. Insufficient drawing documentation leads to production delays and reworking of assembly procedures in the production area. The purpose of technical drawing is to display the requirements for a functional design with clear and relevant information so that the product is manufactured and these requirements are verified [25-27]. The methods used in the design process should be clear and concise so as not to cause confusion in the interpretation of the design and, consequently, should allow all participants in the process to interpret the design requirements [28].

2 Definition of the geometric product specification

The production produces parts that are not completely accurate and those show deviations from the nominal values and also from each other. Components are measured to compare with the specification [29,30]. The geometric product specification (GPS) defines in the engineering drawing the shape (geometry), dimensions, and surface characteristics, which ensure the optimal function of the part together with the scattering around the optimum, which still ensures a satisfactory function [31].

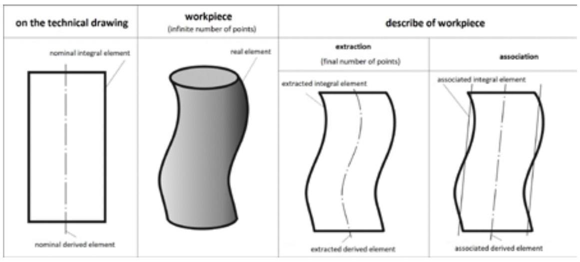

Figure 2. Definitions of geometric elements.

The aim of improving the geometric product specification system is to provide tools for effectively managing variability in products and processes. The committee envisaged a mathematical-based GPS language that allowed the expression of requirements for a wide range of component elements. It uses uncertainty as an economic tool to allow optimal allocation of resources between specification, production, and verification. The GPS language is based on sentence combinations, the graphical representation of which is given by the nominal model of the component. This model consists of nominal ideal areas (Fig. 2). GPS language semantics is based on an abstract geometric model of a part. This model consists of imperfect surfaces.

The integrated GPS system for workpiece geometry specification and verification is an improved engineering tool for product development and production. The system is necessary because the company in the international environment is by carrying out certain activities using external resources (outsourcing), rapidly introducing advanced technologies, new production processes, new materials, and visionary products. The aim of GPS enhancement is to provide tools for the cost-effective management of variability in products and processes. This can be achieved by using a more precise way of expressing the functional requirements of the workpiece, complete and well-defined specifications, and integrated verification approaches. his improved GPS system has clarified the current practice and harmonization of the work of other relevant technical commissions (TC) of the International Organization for Standardization (ISO). This harmonization e.g. enables better integration with 3D CAD / CAM / CAQ systems.

3 Geometric dimensioning and tolerance

Geometric dimensioning and tolerance (GD&T) is a system for defining and communicating within technical tolerances. It is a set of instructions designed specifically for dimensioning and designing so that the part is correctly interpreted and also allows the designer's intention to be translated into all stages of the product cycle. Provides instructions for drawing and dimensional inspection.

GD&T uses markers and computer-aided three-dimensional body models in the drawing documentation that explicitly describe the nominal geometry and its tolerances. GD&T finds the widest application in mass production, where the interchangeability of manufactured components without counterparts is necessary.

The basic idea of GD&T is to determine the base of a part or assembly group element. This, of course, concerns the actual location and functional correlation. Bases are selected as starting points (starting points) for dimensioning and using tolerances or tolerance zones. Functional bases must be selected. Functional bases are simply one of the components of a part that determine the actual position of the part in the manufactured assembly (product). The use of any other basic system, such as axes, changes the overall tolerance.

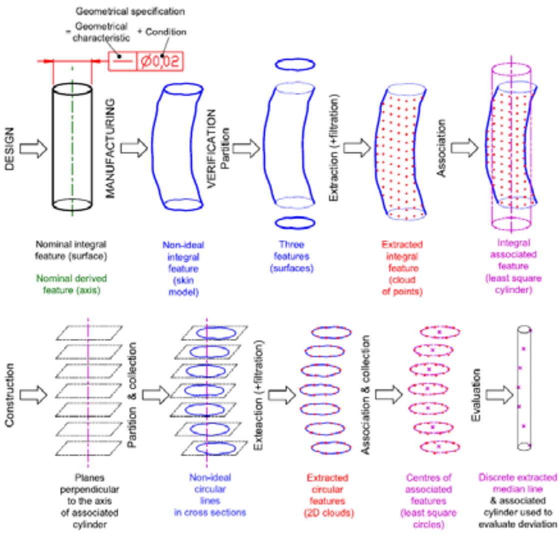

Figure 3. Definition of the basic idea of geometric dimensioning.

Geometric tolerances are determined on the basis of functional requirements for the product, and functional areas of the product and may be affected by the production and inspection of finished products. In this process, they are used in addition to dimensional tolerances and to check more accurate product profiles and shapes. Geometric tolerances are only used if the profile or shape has a certain function and errors could impair its performance.

The geometric tolerance applied to an element defines the tolerance zone in which the element must be located. In these tolerance zones, there must be extracted (real) elements, axes, cylindrical surfaces, planes of symmetry, common axes of holes, and the like (Fig.3).

By geometric tolerance we mean tolerances of shape, direction, and position. The basic concepts of geometric tolerance are deviation and tolerance. The term deviation is used to describe the geometry of actual surfaces and profiles in general and to uniformly evaluate the results of actual profile and surface measurements. Tolerances are generally defined only as of the maximum permissible numerical values that determine the characteristic dimension of planar or spatial tolerance fields. The tolerance fields must be clearly defined in terms of shape and size, as well as in terms of assignment to the shape element under consideration. The types of geometric tolerances are marked on the technical drawing with a graphic symbol and an additional mark.

3.1 Shape tolerances applied to shaft drawings

Shape tolerance is the largest allowable shape deviation value. The shape tolerance field is the area in space or in the plane in which all points of the actual element under consideration must lie within the range of the reference section. The width or diameter of the tolerance field is determined by the tolerance value, and its position relative to the actual area is determined by the packaging element. The shape deviation is quantified as the largest distance of the actual area (actual profile) from the packaging area (packaging profile) in the normal direction to the packaging area (packaging profile).

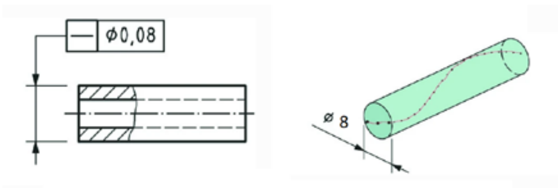

Figure 4. Straightness tolerance.

The application of a simple dimensioning of the straightness tolerance for the shaft is shown in Figure 4. The extracted (actual) canter line of the cylinder for which the tolerance is intended must be located inside a cylinder zone with a diameter of 0.08 mm.

The principle of independence applies in general, but the limiting conditions are the condition of the packaging element, which is related to the different tolerances of the geometric elements. In order to achieve economic efficiency of production, it is necessary to mention what contributes to and helps the fitting of parts. The condition that contributes to the fitting of parts is the condition of maximum material.

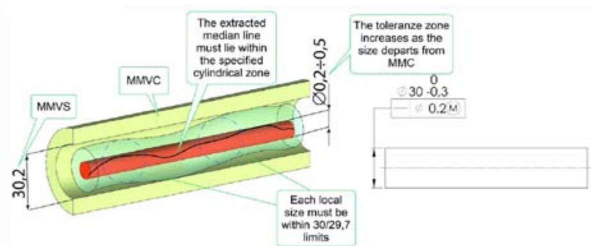

Figure 5. Combination of straightness tolerance and material maximum.

An example of the effect of the material maximum condition at the cylindrical end of the shaft is shown in Figure 5. The material maximum condition is indicated by the symbol M in the tolerance box next to the shape or position tolerance. In this case, the geometric element must not exceed the applicable condition. When a straightness control is applied to a feature of size, it is possible to use the maximum material requirement. The combined effect of the size error and the straightness error generates a virtual size (MMVS), which represents the worst possible mating condition.

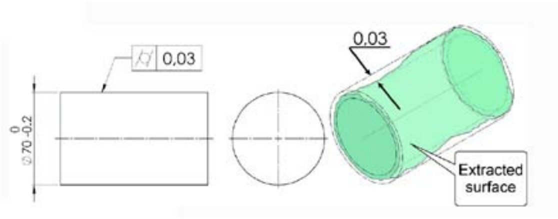

Figure 6. Example of a roundness tolerance rule at the cylindrical shaft end.

Other common tolerances applied to shaft drawings include cylindricality tolerances (Fig. 6). The deviation of the cylindricality is the greatest distance of the points from the actual area of the packaging cylinder in the range of the reference section. The cylindrical tolerance field is the area in space bounded by two coaxial cylinders spaced apart by a length equal to the cylindrical tolerance T = 0.03. The cylindrical deviation is used in production drawings of shafts and drawings of gearbox bodies, to tolerate the cylindricality of holes.

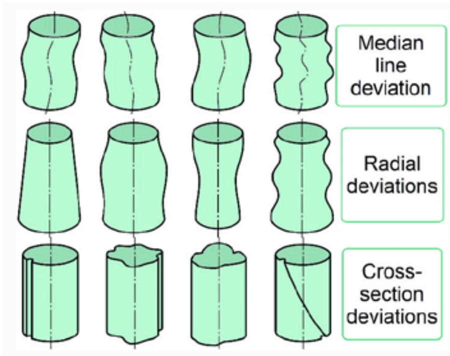

Figure 7. Deviations from the cylindrical shape.

The actual cylindrical surface may be subject to cylindrical deviation errors as a combination of simple elements caused by machining errors and/or deformations due to thermal, pressure, or stress effects, tool wear, and/or vibration. These deviations can be classified according to Figure7.

3.2 Position tolerances applied to shaft drawings

Position deviation is the deviation of the actual position of the assessed element from its nominal position, which is determined by the nominal length and angular dimensions between the given element and the base, resp. among the elements considered (when no base was specified). The position tolerance field is the area in space or in a given plane in which the assessed packaging element must lie within the scope of the reference section. The width or diameter of the tolerance field is determined by the tolerance value.

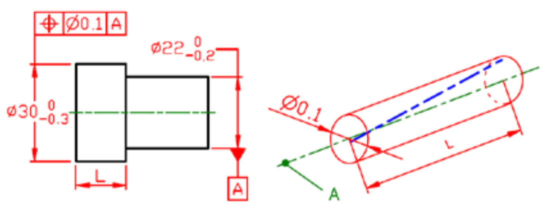

Figure 8. Example of position tolerance.

For the location of a derived element (axis plane or symmetry), the standard applies only the position tolerance. According to this regulation, the position tolerance is applied to the axis (plane of symmetry) of an unrelated actual paired envelope. In Figure 8, the position tolerance rule is specified to control the coaxiality of the two-stage shaft flange with respect to base A.

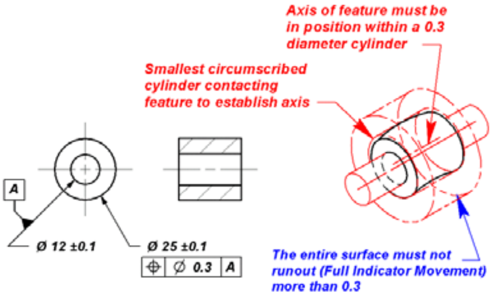

Figure 9. Example of position tolerance.

According to the Standard, when no modifiers are present, the implied condition is regardless of feature size as shown in Figure 9. In this case, the axis of the datum feature and the feature being controlled must be determined to find the error in coaxiality. Although this control may be applied to bearings and dynamic balance applications, the job can usually be accomplished at a lower overall cost by using one of the runout controls.

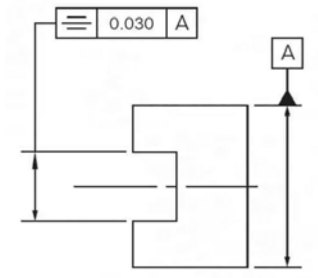

Figure 10. Example of symmetry tolerance.

Another tolerance used in the drawing documentation of the gearbox shafts is the center plane symmetry tolerance. A simple example of a prescription is shown in Figure 10.

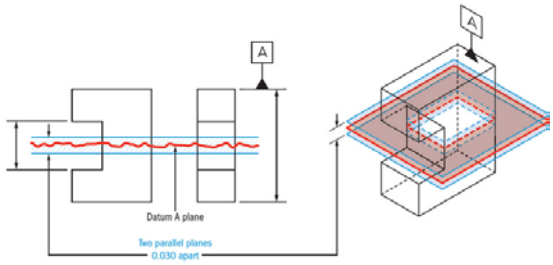

Figure 11. Symmetry tolerance zone.

In Figure 11, the median plane extracted must be between two parallel planes spaced 0.030 mm apart.

3.3 Example of GD&T application in a gearbox shaft drawing

Figure 12 shows a part of the bearing of the input shaft of the gearbox transmission, i.e. a part of the assembly drawing. In the example of shaft dimensioning, we will clearly show the regulation of dimensioning of individual tolerances on the production drawing of the shaft.

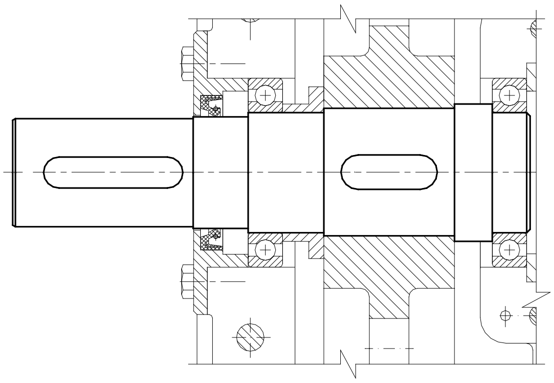

Figure 12. Part of the assembly drawing - input shaft positioning in bearings.

An example of the prescription of some tolerances on the shaft is shown in Figure 13.

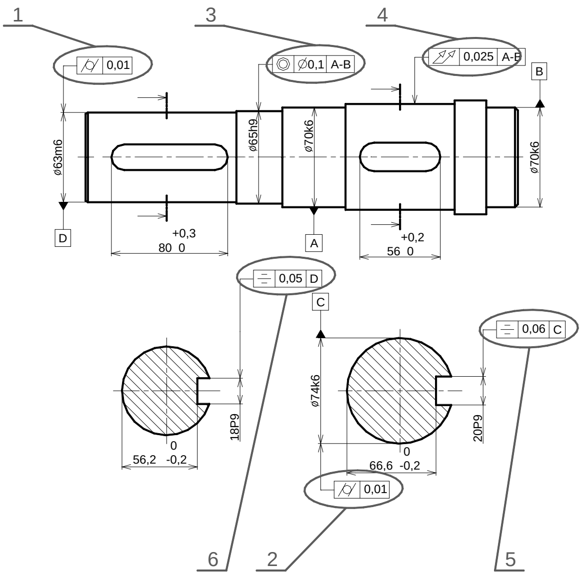

Figure 13. Prescription of geometric tolerances on the shaft – example

Figure 13 shows the tolerances for the shaft. Under item position numbers 1 and 2, this is the cylindricity tolerance rule. The concentricity tolerance is dimensioned under item position number 3. An example of the total circumferential runout tolerance rule is under item position number 4. An example of a symmetry tolerance rule is indicated by item position numbers 5 and 6.

4 Conclusion

An important part of the production is the drawing documentation, which contains all the necessary information about the product so that it can be used to create the desired and especially the right product. We create all drawings of parts and assemblies according to relevant and current standards. The drawing documentation may contain all the essentials that are needed throughout the production life cycle of the product, such as material, dimensions, tolerances, product structure, and a lot of other data needed for production, inspection, testing, and subsequent delivery to the customer.

The geometric product specification, abbreviated GPS, defines in the engineering drawing the shape (geometry), dimensions, and surface characteristics, which ensure the optimal function of the part together with the scattering around the optimum, which also ensures a satisfactory function. The production produces parts that are not completely accurate and those show deviations from the nominal values and also from each other. This plays an important role in prescribing the tolerances of the individual functional dimensions on the production drawings of the component. Based on the analysis of the application of the basic principles of the geometric product specification, the drawing documentation of each non-standard gearbox element must comply with several rules. For assembly, this is an important role in the fact that all dimensions must have the prescribed tolerances.

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