PolTolerances-AC – Dimensions, Tolerances and Fits for (Moulded)Parts under Application Conditions

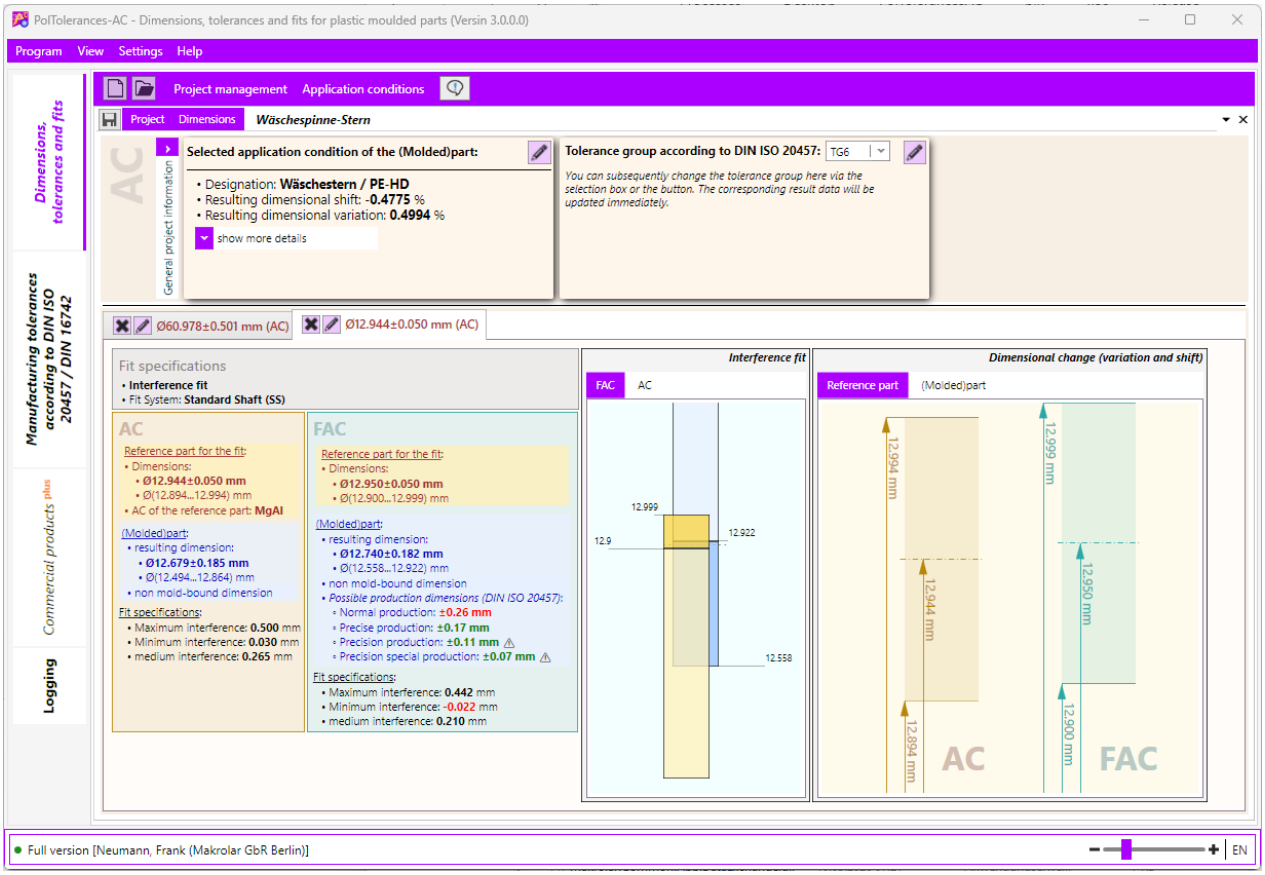
Inhaltsverzeichnis

Dimensions, Tolerances and Fits under Application Conditions (ACs) 3
Introduction 3
Functions (Overview) 4
Quick start 5
DIN ISO 20457 / DIN 16742 5
Operation 5
management/definition of application conditions 5
Introduction 6
Operation 7
Create a new application condition 8
Project Management 9
new project 10
Entry/Edit of (Molded)Part Dimensions 11
independent dimensions 12
fit dimensions 14
Modify Data Afterwards 16
Print / Preview 16
DIN ISO 20457 / DIN 16742 (PolTolerances 3.x) 17
PolTolerances - preface 18
Quick start 18
Application and decision aids 19
Tolerance principles and recommendations 19
scope of application 20
Definition equations for processing shrinkage 20
Causes and influencing factors on the processing shrinkage (VS) of non-porous plastics 21
Tool binding of the moulded part dimensions 22
Testing and structuring of the stiffness/hardness level of polymers without solid additives 22
Notes on the classification of tolerance groups according to process and moulding compound 23
Nominal sizes definitions 24
Dimensional reference planes, causes of dimensional changes and moulded part acceptance conditions 24
Notes on the classification of the tolerance series 27
How to use 27
Measurements input 28
Project management 29
Tolerance values tables 30
Determine realizable tolerance series 31
Processing shrinkage ranges 32
Feasibility of required functional dimensions 32

Dimensions, Tolerances and Fits under Application Conditions (ACs)

The main window of the software module “Dimensions, Tolerances and Fits”.

The figure shows an example project in which two fit dimensions were defined under application conditions (AC). The resulting dimensions and results are displayed under the fabrication acceptance conditions (FAC).



Introduction

The basis for (molded) part development, mold design and manufacturing are the service or application conditions (**AC**) of the (molded) part. If dimensional changes occurring over time after manufacturing are relevant to the function of the parts, these must be taken into account when defining the dimensional position, dimensional shift and dimensional scatter.

Starting from application-related or functional requirements for dimensions, tolerances and fits, the values must be transformed to the respective other dimensional reference level.

The following two dimensional reference levels are distinguished:

- Fabrication acceptance conditions (**FAC**)
- Application conditions (**AC**)

The dimensional reference levels are defined as follows:

- **AC**: Application conditions (all operating and storage conditions during the period of use and after manufacturing, insofar as they influence dimensional stability and functional performance)
- **FAC**: Fabrication acceptance conditions of (molded)part production (when molded parts are stored after manufacturing until acceptance at 23 °C ± 2 K and 50 % ± 10 % relative humidity, and are inspected no earlier than 16 hours and no later than 72 hours after production)

f, for example, the dimensions are available under the fabrication acceptance conditions (FAC) or have been calculated accordingly, they can additionally be evaluated for plastic molded parts using **DIN ISO 20457** (also included in this software). This means assessing **whether**, **how**, and **under which conditions** the dimensions, tolerances and fits under FAC can be realized. This may also lead to the need to refine previously made decisions regarding the (molded)part material and/or the supplied components. In turn, this may require corrections or refinements to the mold design. Consequently, this is generally an iterative process.

The definition of application conditions (AC) and the resulting material-dependent dimensional changes, if applicable, form the basis for the calculation and transformation to the respective other dimensional reference level.

Dimensional changes (i.e., previously defined ACs) can be assigned to:

- the (molded)part,
- the respective fit reference part, and/or
- individual dimensions (e.g., for wear, expansion, or compression).

The functions of the software are **not limited to plastic parts**. In practice, plastic parts are often used in combination with components made from other materials (e.g., in fits or with inserts). Therefore, the software can also **be used without restriction** for **components made of other materials**.

Functions (Overview)

The main focus of the software is the calculation of **dimensions**, **tolerances** and **fits** of (molded)parts **under application conditions** (AC). The calculation methods and concepts are not limited to plastic components.

- Manage application conditions (AC) (create, edit, delete).
- Define multiple dimensional changes for each application condition.
- Predefined application conditions can be reused across different projects.
- For dimensional changes such as *thermal expansion*, *thermal contraction* and *swelling*, **additional calculation algorithms** are available (specifically for plastic parts).
- Manage projects / (molded)parts (create, edit, delete).
- Define and edit one or more individual part dimensions within a project.
- Define and edit one or more fits within a project.
- Scaled graphical representation of fits and individual dimensions including their dimensional changes for both dimensional reference levels (AC and FAC).
- Previously defined application conditions can be individually assigned to the (molded)part, individual dimensions and/or fit reference parts.
- Immediate calculation of dimensions, tolerances and fits in the respective other dimensional reference system.
- Immediate evaluation of dimensions in the dimensional reference system FAC using the corresponding software functions (according to DIN ISO 20457).
- Application conditions and/or the tolerance group (DIN ISO 20457) can be easily modified within the project and their effects evaluated immediately.
- All decisions regarding dimensions, limit deviations, fit specifications, etc. can be changed at any time; the effects are immediately visible.
- Print the list of managed application conditions including all details.
- Print all details of a project.
- Manage predefined application conditions as a file.
- Manage projects / (molded)parts, each stored in its own file.

The software also includes **all functions** related to **DIN ISO 20457 and DIN 16742**. These functions are identical to those provided in our software *PolTolerances (3.x)*.

Quick start

The management/definition of application conditions (AC) and the editing of (molded)part projects are initially two independent work steps within the software.

During the editing of the (molded)part projects, the previously defined application conditions are then assigned to the (molded)part, the fit reference parts and/or individual dimensions.

The software is designed so that a complete (molded)part can be processed, for example when it is used in an application together with mating parts.

Quick guide

1. Create a new project and define the basic settings and parameters.
2. Once the project has been created with the basic data, add a fit dimension if required.
3. Then add an independent dimension if required.

You can save your changes to files at any time. If a file has not yet been created, you will be prompted to specify the file name and storage location.

DIN ISO 20457 / DIN 16742

Tolerances for Plastic Molded Parts According to DIN ISO 20457 / DIN 16742

- Both *PolTolerances-AC* and *PolTolerances (3.x)* support direct tolerancing of linear dimensions including general tolerances, direct position tolerancing with cylindrical tolerance zones, and profile tolerances for form deviations in accordance with the above-mentioned standards. These calculations and evaluations are performed under the fabrication acceptance conditions (FAC) of molded part.
- Detailed information can be found in this help section under "DIN ISO 20457 / DIN 16742 (PolTolerances 3.x)".

Depending on the type of project, dimensions are specified or calculated in the dimensional reference system (FAC). Whenever possible, these dimensions are automatically evaluated by the software functions (according to DIN ISO 20457) and the corresponding results are displayed.

Operation

The software is suitable for a wide range of tasks related to the analysis of dimensions, tolerances and fits under application conditions (AC) as well as under the fabrication acceptance conditions (FAC).

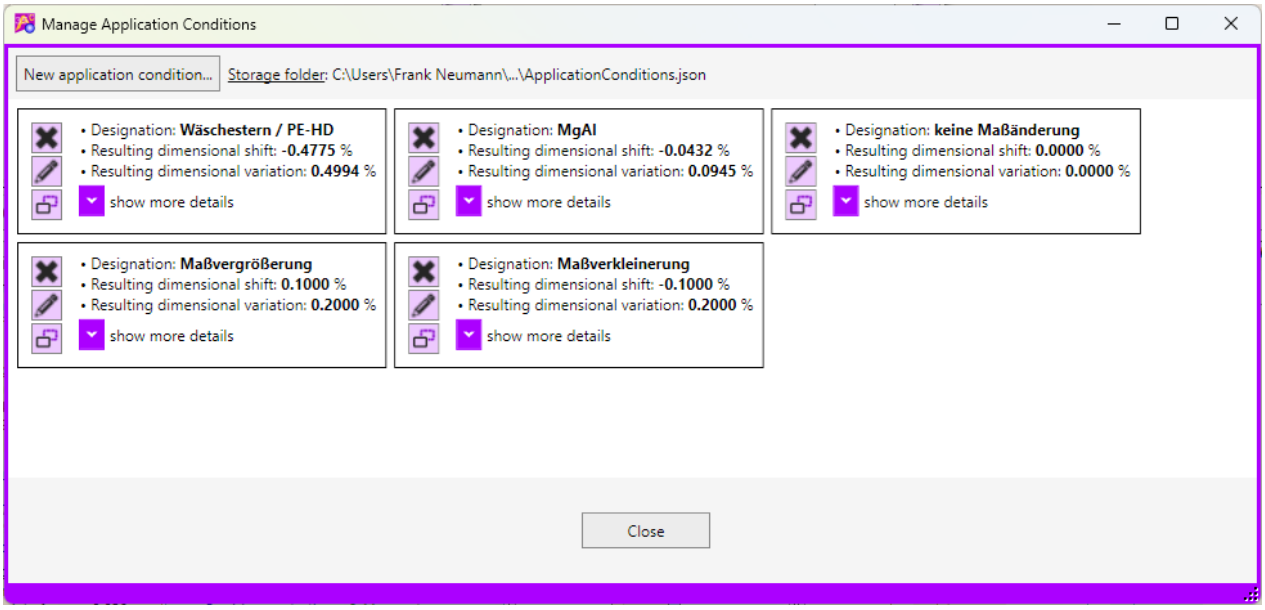
The functions of the software are not limited to plastic parts. In practice, plastic components are often used in combination with parts made from other materials (e.g., fits, inserts, etc.).
Therefore, the software can also be used without restriction for components made from other materials.

The most important operating functions are described below.

Management of Application Conditions
Project Management
Printing / Print Preview

management/definition of application conditions

First, application conditions (AC) must be defined in order to transform dimensions and fits into the respective other dimensional reference system.



You can, among other things:

- **create** new application conditions
- **edit** a selected AC afterwards
- **delete** a selected AC
- **clone** an AC as a template for another AC
- **print** the list of all ACs

Notes

- Application conditions are uniquely identified by their name. This means that each defined AC must have a unique designation.
- The assignment to projects, mating parts and/or individual dimensions is carried out via this designation.
- If an AC assigned to a project is deleted, the assignment within the project will be lost. When the project is loaded the next time, a corresponding notification will be displayed.
- The ACs are stored in a “readable” file format. If necessary, create backup copies for data security.
- The storage directory for this file can be changed via the application settings.

Introduction

General

If dimensional changes occurring over time after manufacturing are relevant to the function of the (plastic) parts, these must be taken into account when defining the dimensional position, dimensional shift and dimensional scatter.

The determination of dimensional changes under application conditions (AC) requires the consideration of condition parameters and material properties. If users do not have their own data and experience, they can establish an orientation basis using the determination scheme described below. **The fundamental principle is that the functionally required dimensional stability must be ensured at all times during the service life**.

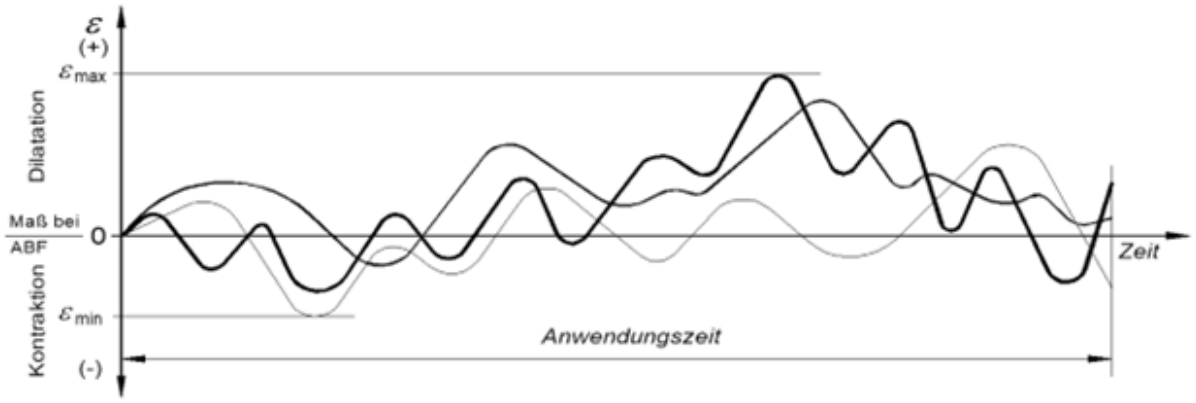
Due to the temperature dependence of material properties, reference temperatures may have to be taken into account. Material data can be obtained from manufacturers’ data sheets or other sources. The software itself also includes a large number of commercial plastic material grades.

The condition parameters result from the specific application environment of the parts. These include

indoor climate conditions, outdoor climate regions of the world, as well as special application conditions caused by heat sources (e.g., engine heat, greenhouse effect, heating systems) and heat sinks (e.g., cooling devices or refrigerated rooms).

Relative Dimensional Changes with Respect to the Acceptance Conditions of Production (ACP)

An arbitrary number and various types of dimensional change progressions during the service life are bounded by the extreme values ε_{max} and ε_{min}.



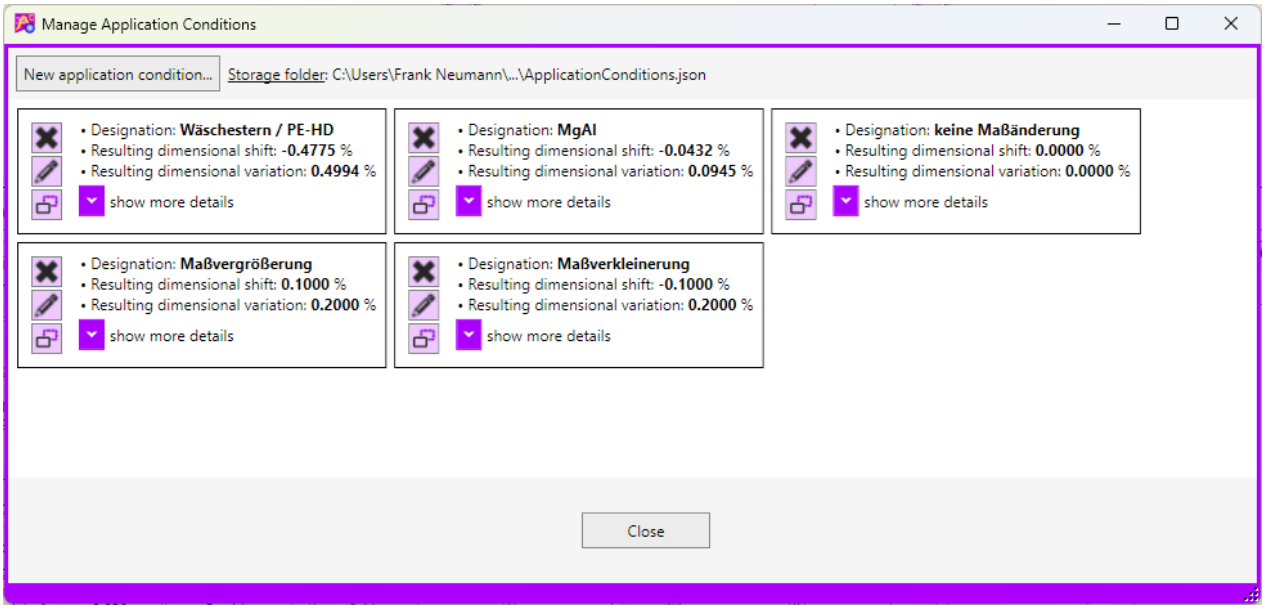
Assuming normally distributed progressions, the mean relative dimensional shift and the relative dimensional scatter are calculated.

If dimensional changes caused by mechanical loads must be considered, they must be differentiated according to elongation and compression. Likewise, possible wear specifications must be taken into account by means of wear rates V (in %), distinguished between internal parts (shafts) and external parts (holes).

Calculation modules to support the definition of application conditions are integrated into the software.

Operation

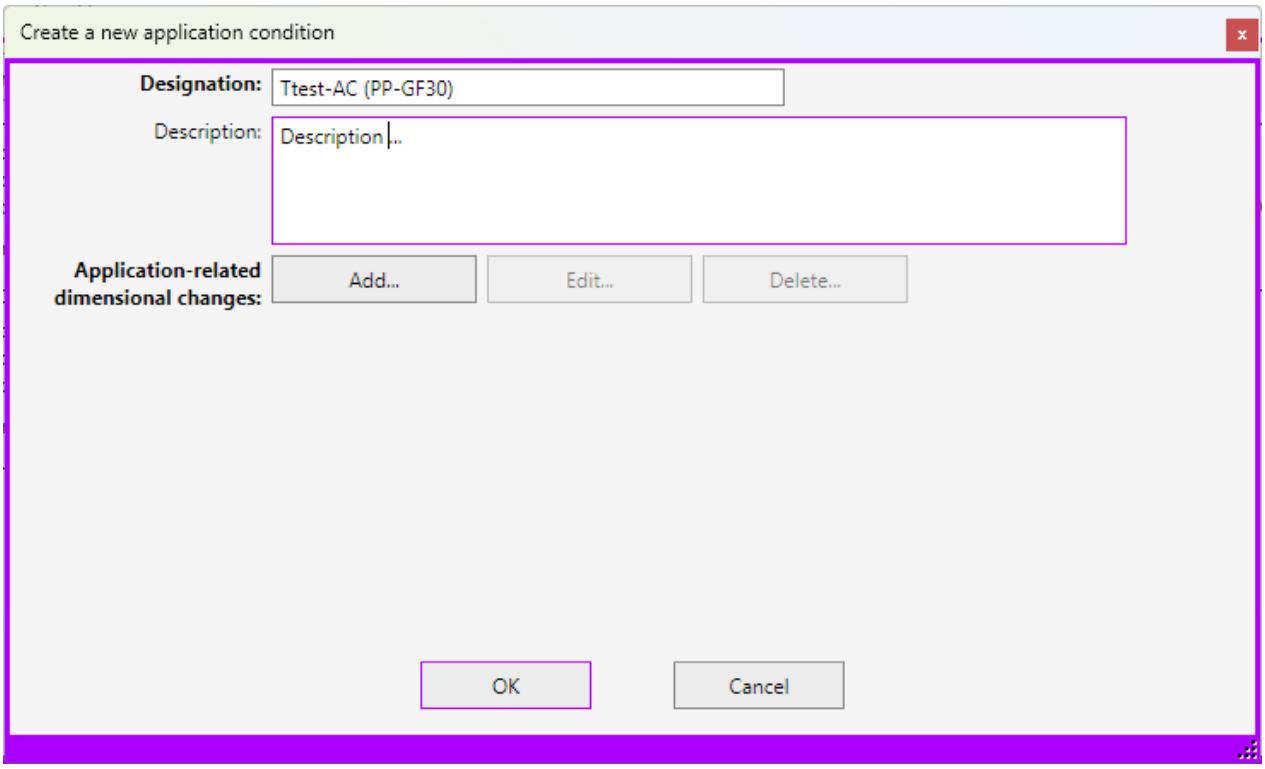
1. In the module main window or in the main menu “*Application Conditions*”, select the function “*Manage…*”.
2. A new window will open displaying the application conditions (ACs) defined so far.
3. Here you can add a new AC or edit an existing one.
4. You can also copy an AC as a template for another AC and then modify it accordingly.



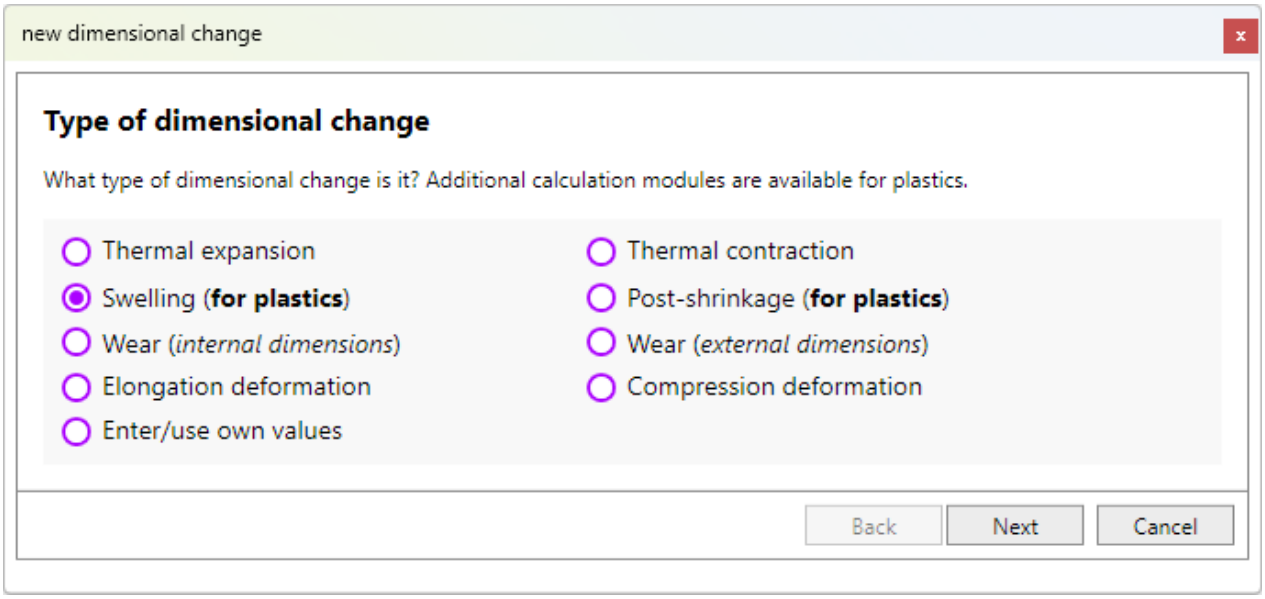
Click [*New Application Condition…*] at the top to create another AC.

See also: Create a New Application Condition

Create a new application condition



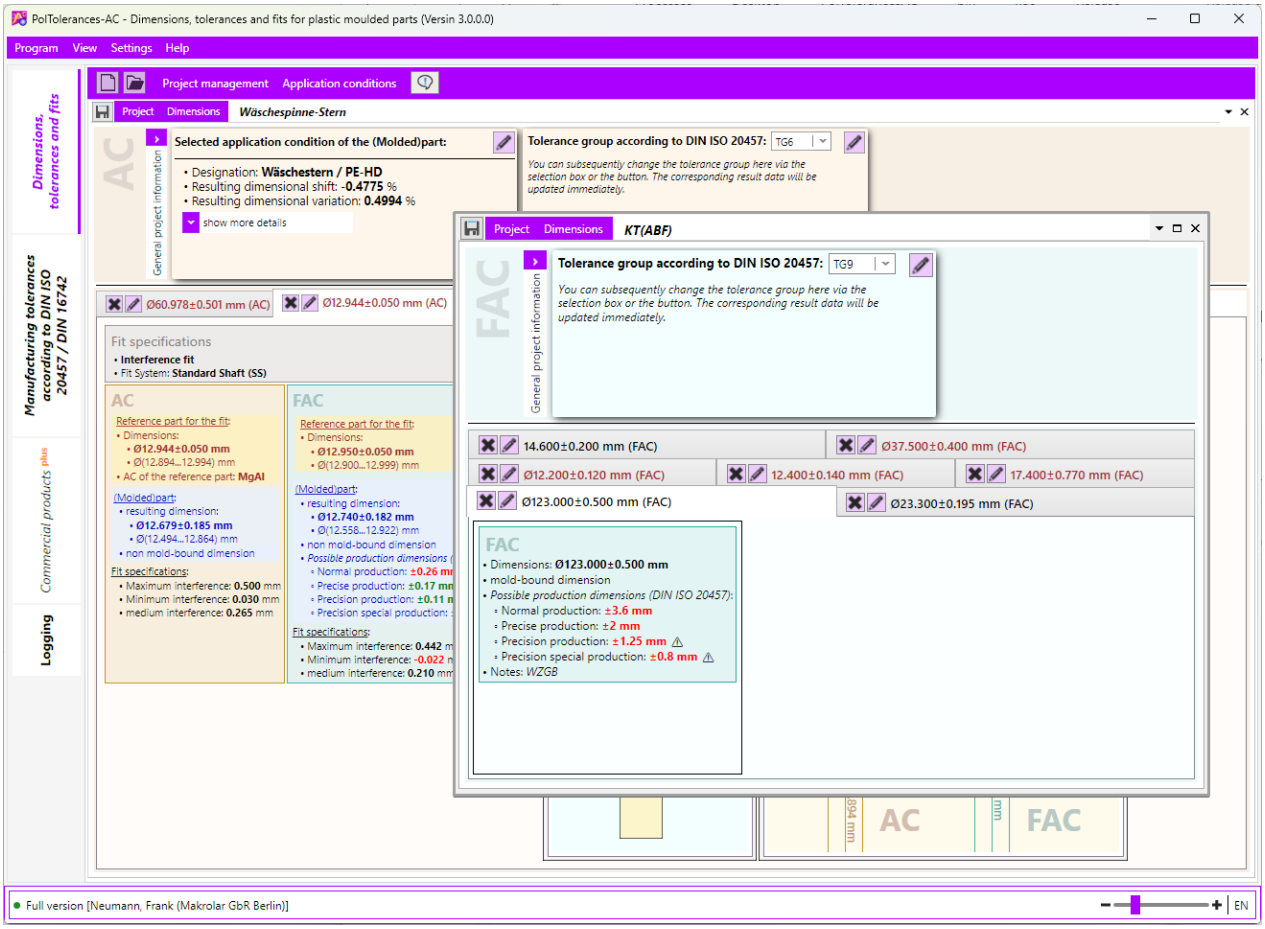
1. Enter the name of the AC. This name must be unique.
2. Optionally, you can add a description.
3. By clicking the [*Add…*] button, you can define one or more dimensional changes.
4. Once you have finished defining the dimensional changes, click [*OK*] to save the AC.



Further details on the individual dimensional changes and their calculation modules are also described in greater detail in the book “Entwicklung und Konstruktion von Kunststoffteilen”

Project Management

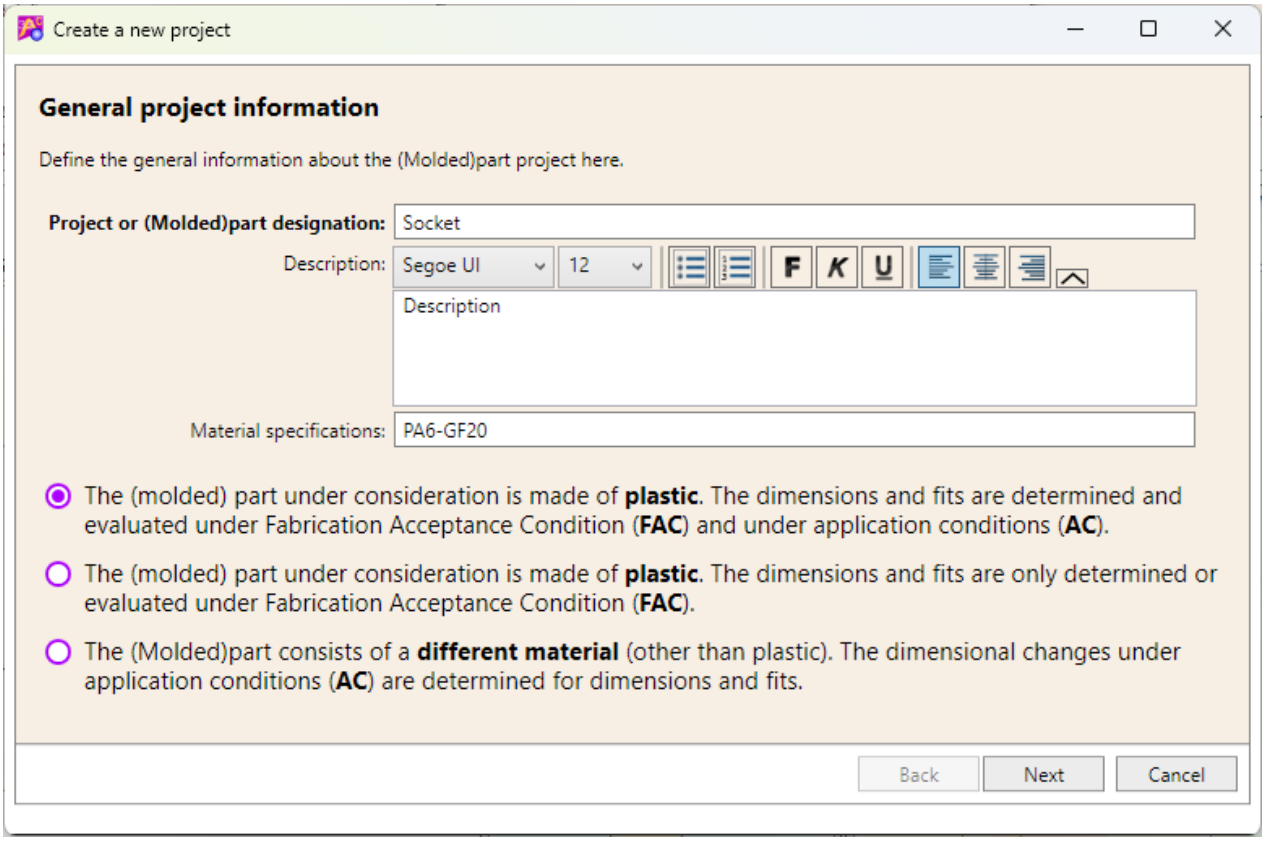
- Projects are stored in individual files.
- In the module main window, several projects can be opened simultaneously.
- The project windows can be arranged or docked differently (via drag & drop).
- Each project window has its own main menu.
- The directory in which projects are stored by default can be changed via the application menu “*Settings*”.



[Create New Project](#)
[Define/Edit (Molded) Part Dimensions](#)
[Modify Data Later](#)

new project

1. In the main menu of the software module, select Project Management → "*New Project…*".
2. A wizard window will open. Follow the instructions on the screen.
3. Enter a name for the project and optionally add a description and material information.
4. Select the general project type.
5. Depending on the project type, the application condition (AC) determining the (molded)part and/or the tolerance group according to DIN ISO 20457 must be assigned.
6. If you have not yet created an AC, you can do so within this context.
7. Finally, click [*Finish*].

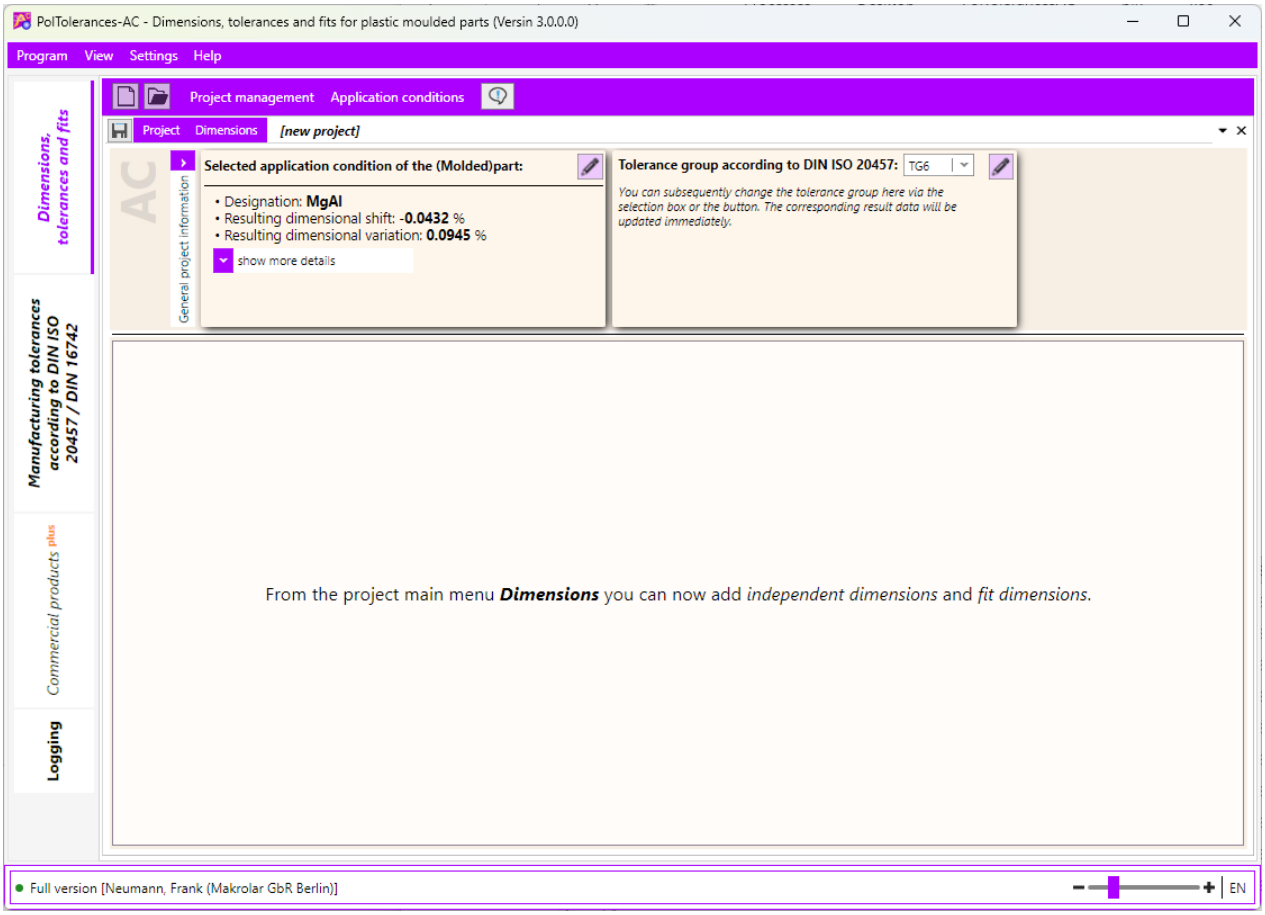


Afterwards, independent dimensions and fit dimensions can be added.

Entry/Edit of (Molded)Part Dimensions

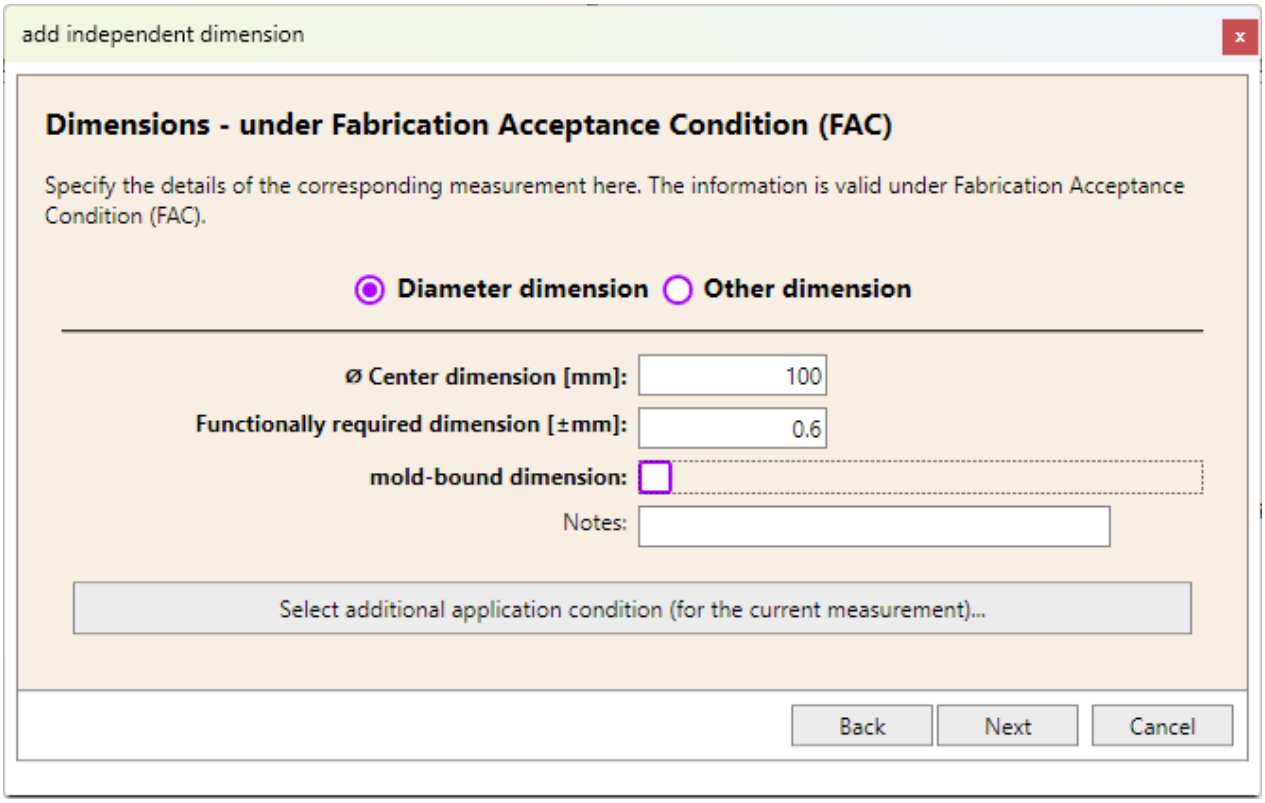
Once you have created a new project, multiple independent dimensions and fit dimensions for a (molded)part can be defined and edited.

- Independent Dimensions
- Fit Dimensions

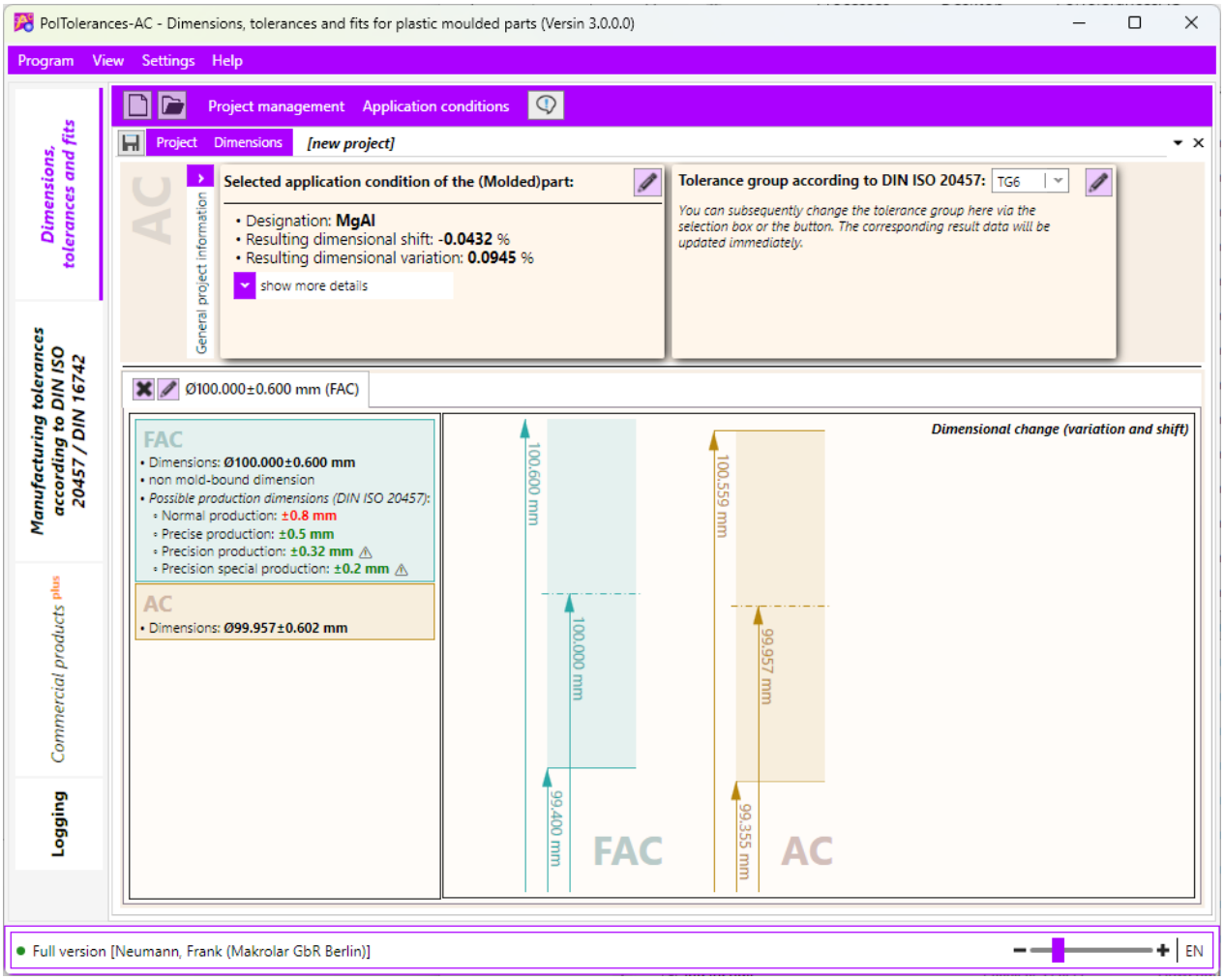


independent dimensions

1. In the project main menu, select *“New Independent Dimension…”*.
2. A wizard window will open.
3. Follow the instructions on the screen.
4. Finally, click [*Finish*].



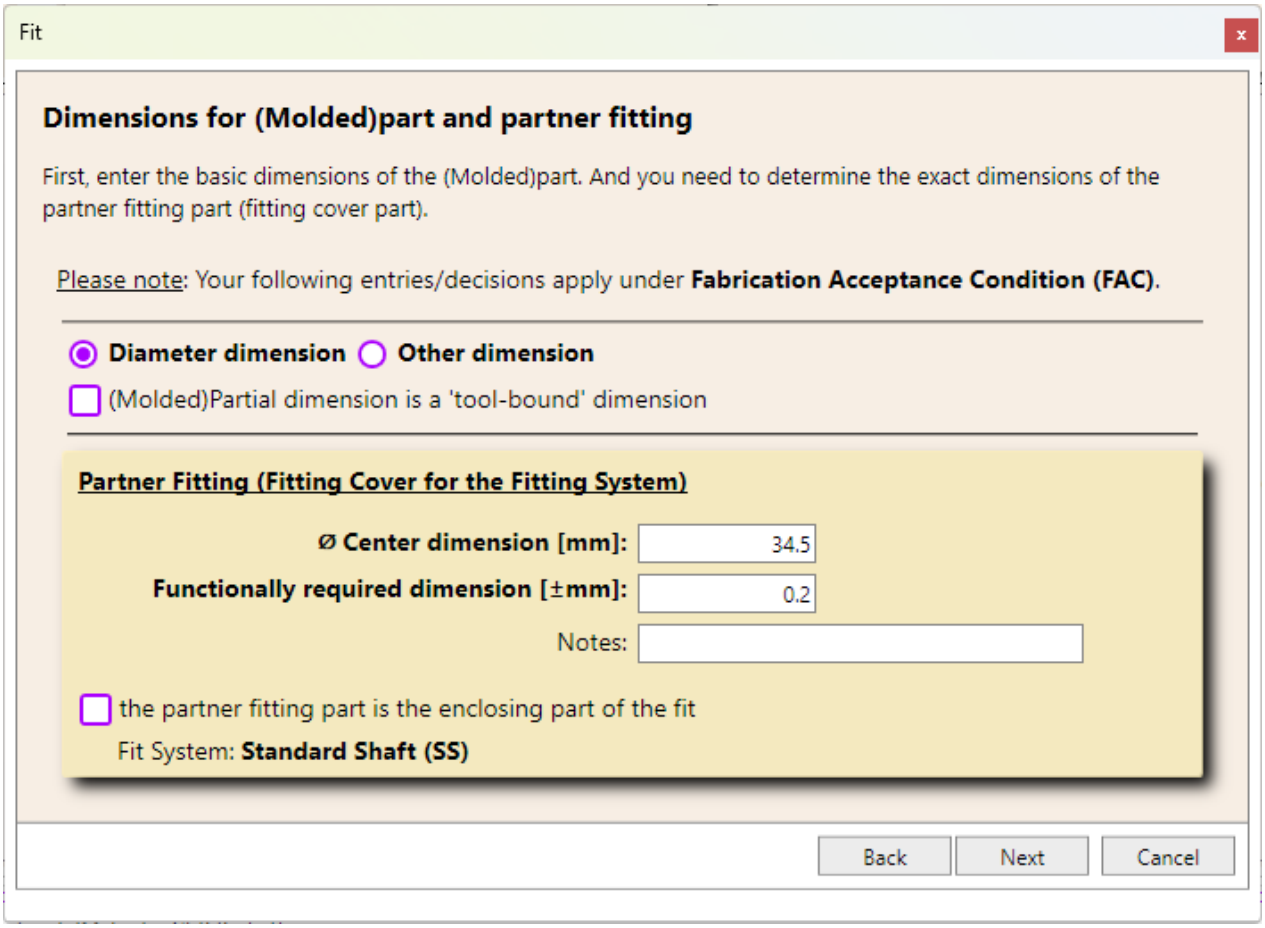
The new dimension is added as a tab in the module main window.



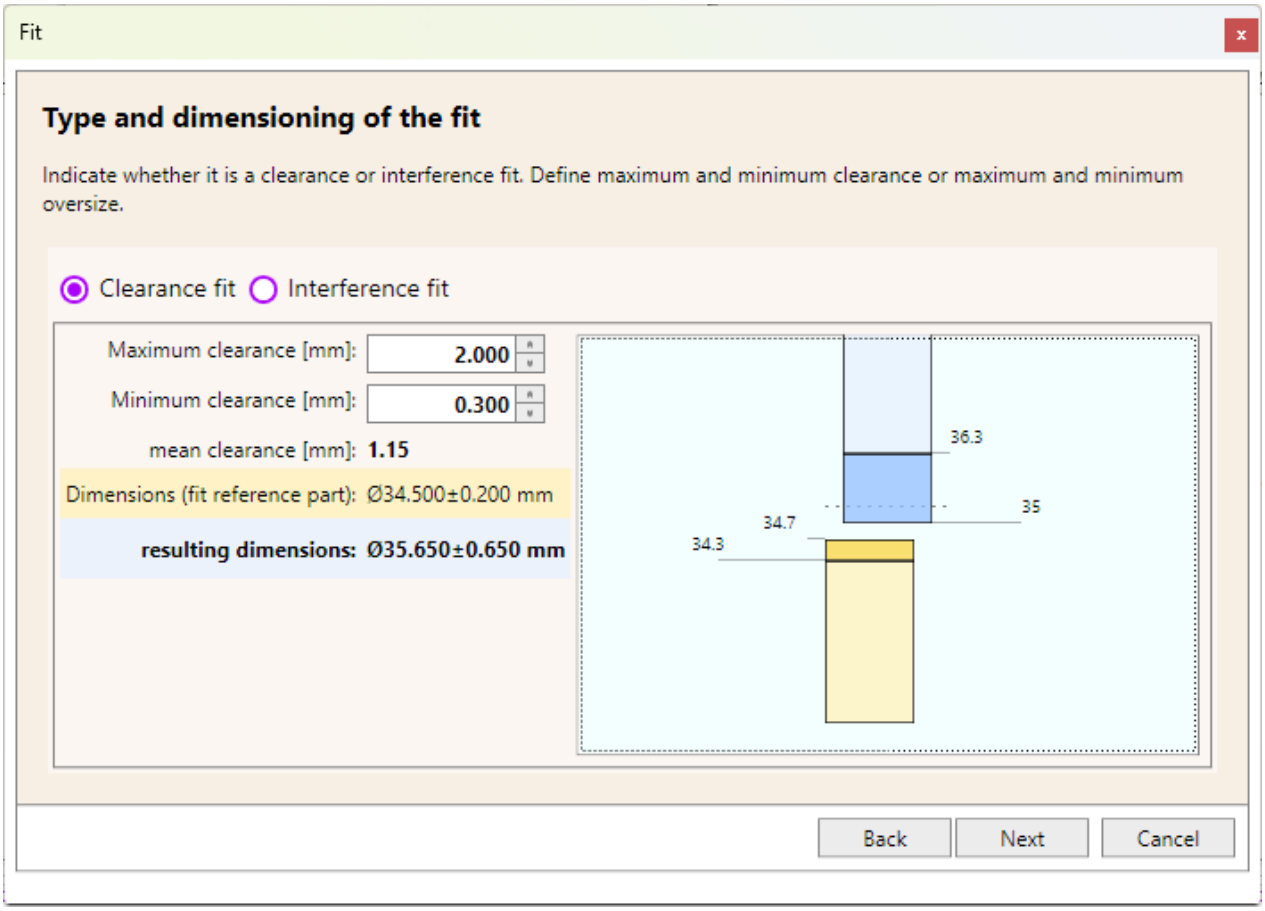
fit dimensions

1. In the project main menu, select "*New Fit Dimension…*".
2. A wizard window will open.
3. Follow the instructions on the screen.
4. Finally, click [*Finish*].

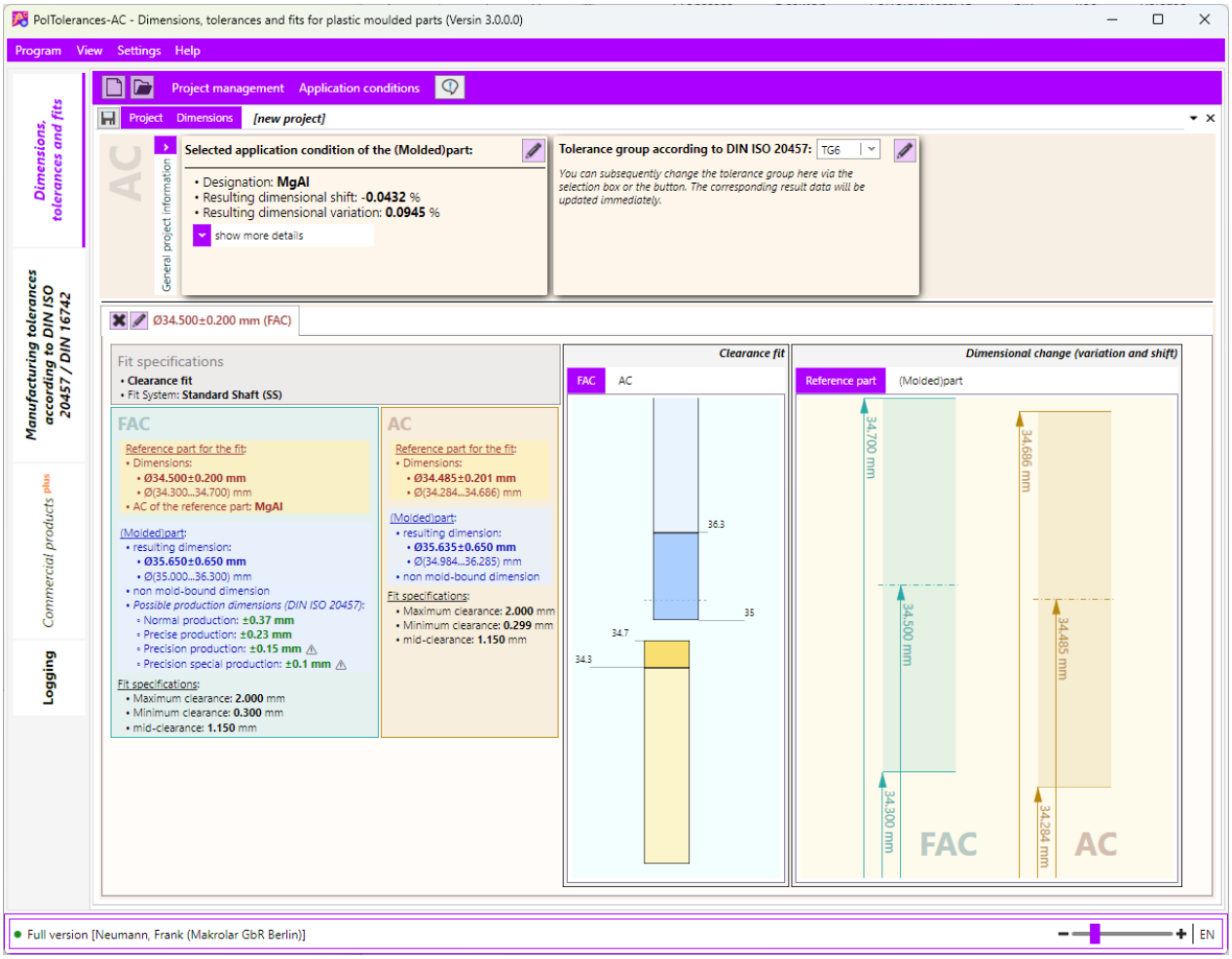
First, enter the basic data for the (molded)part and the detailed specifications for the fit reference part in the selected dimensional reference system.



The fit specifications are then entered. The resulting dimensions of the (molded)part are calculated and displayed.



The new fit dimension is added as a tab in the module main window.



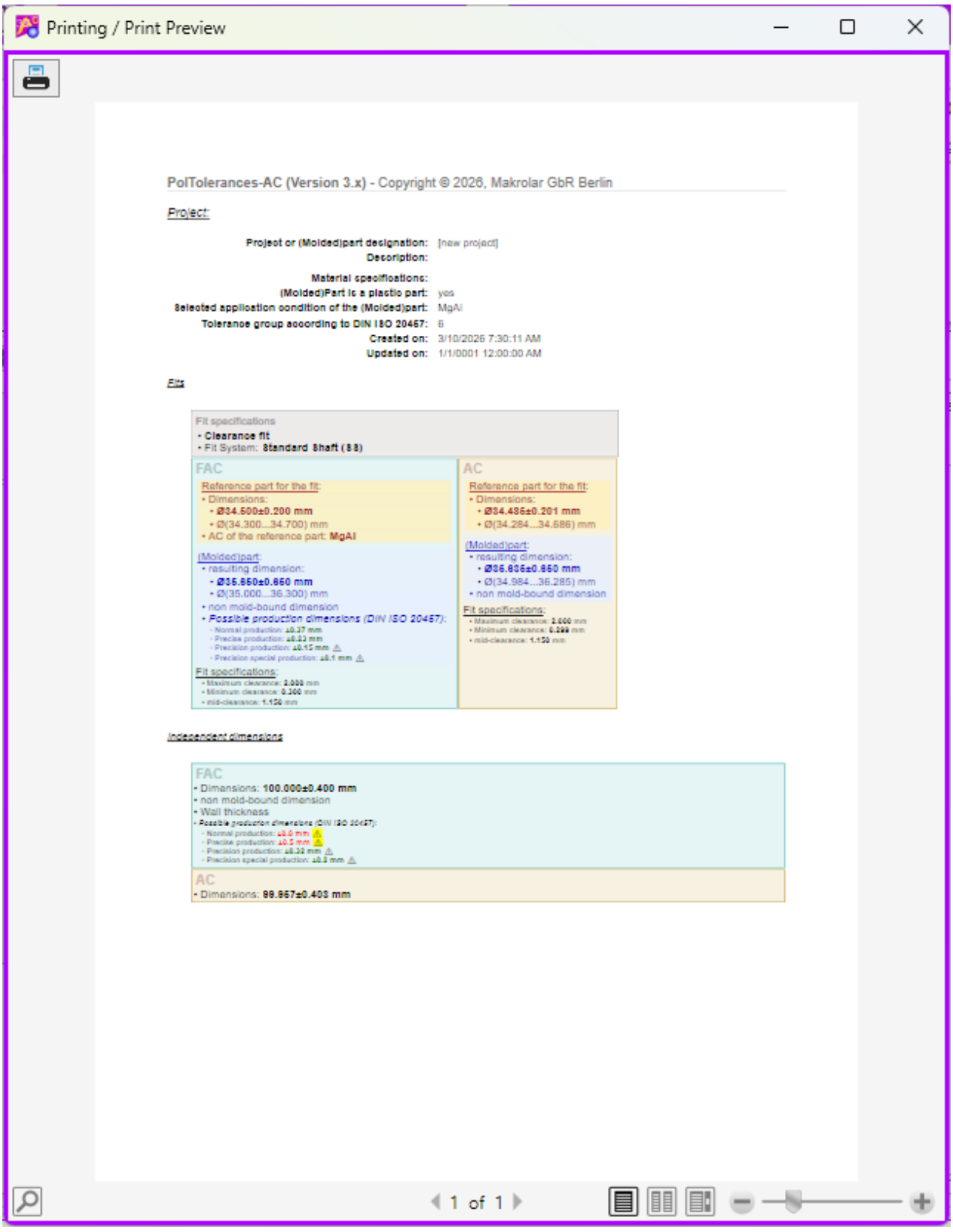
Modify Data Afterwards

After creating a project, the following data can be modified later. Immediately after the data has been changed, all results are updated and displayed instantly whenever possible.

- Application condition for the project
- Tolerance group (DIN ISO 20457) for the project
- Independent dimensions
  - Mid-dimension and limit deviations
  - Dimension-related AC
- Fit dimensions
  - Mid-dimension and limit deviations of the fit reference part
  - AC of the fit reference part
  - Maximum/minimum clearance or maximum/minimum interference
- Project name
- Project description (optional)
- Project material information (optional)

Print / Preview

Each project can be printed individually. In addition, it is possible to print all defined application conditions, including all detailed information. A print preview is available for both options.



DIN ISO 20457 / DIN 16742 (PolTolerances 3.x)

With the ***PolTolerances-AC*** software, you have also acquired all functions of the ***PolTolerances 3.x*** software.

In the following sections, you will find the software description of ***PolTolerances 3.x***.

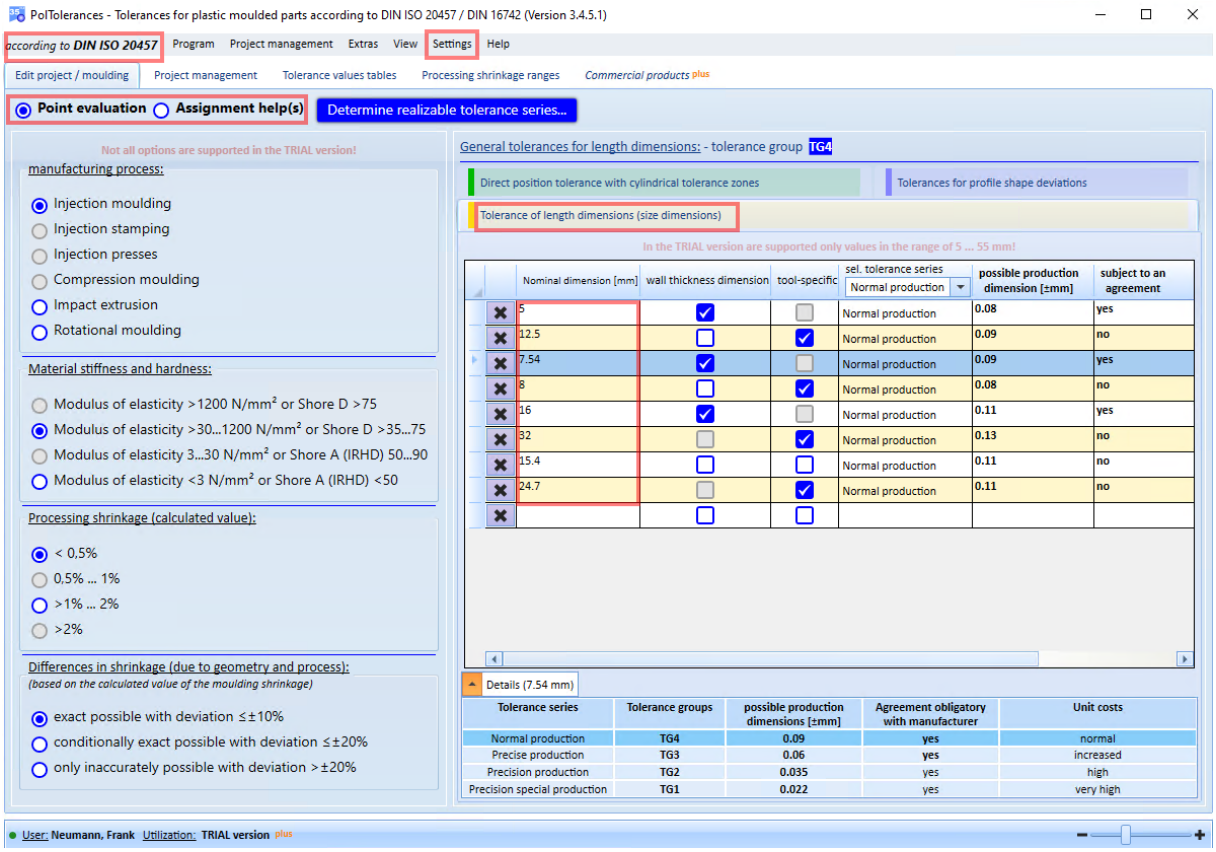
PolTolerances - preface

Tolerancing of plastic molded parts (according to ISO 20457/DIN 16742)

It is important for the manufacturer of plastic moulded parts and for the customer to agree meaningful dimensional tolerances. Too high accuracy requirements lead to high costs, e.g. for tools, in the production of moulded parts and thus in quality assurance. The dimensional, shape and position deviations in the application and production of plastic moulded parts cannot be compared with those of metal parts, as the properties of plastics and metals may differ considerably in application and production. The application of the new ISO 20457/DIN 16742 is recommended in order to take the technically feasible accuracies into account during the development of moulded parts.

Quick start

The main window of the software ...



The following sequence is a suggestion. The order of your inputs/decisions is only of secondary importance. Results are displayed or updated immediately when all required inputs and decisions are available.

1. Specify which tolerance values are to be used for the calculation. You can choose between "***DIN ISO 20457***" and "***DIN 16742***" (*Settings* menu).

2. Specify the evaluation method for determining the tolerance group. You can choose between "***Point evaluation***" and "***Assignment help(s)***" in the software.

3. Make all the necessary entries and decisions for the selected evaluation method

4. Enter the part dimensions to be toleranced in the corresponding lists "***Tolerancing of length dimensions***", "***Tolerances for profile shape deviations***" or "***Direct position***

tolerancing with cylindrical tolerance zones".

5. Optionally, you can additionally specify a required functional dimension/tolerance per nominal dimension. This (these) is then automatically compared with the possible manufacturing dimension/tolerance.

6. If necessary, save your entries and decisions in a file. We recommend that you create a corresponding file for each molded part.

Application and decision aids

1. Tolerance principles and recommendations
2. scope of application
3. Definition equations for processing shrinkage
4. Causes and influencing factors on the processing shrinkage (VS) of non-porous plastics
5. Tool binding of the moulded part dimensions
6. Testing and structuring of the stiffness/hardness level of polymers without solid additives
7. Notes on the classification of tolerance groups according to process and moulding compound
8. Nominal sizes definitions
9. Dimensional reference planes, causes of dimensional changes and moulded part acceptance conditions
10. Notes on the classification of the tolerance series

Tolerance principles and recommendations

- The principle of independence according to DIN EN ISO 8015 applies, deviations from this principle (e.g. envelope condition) must be agreed between the contracting parties.
- Shaped part drawings or CAD data sets correspond to the nominal geometry. The tolerances are given as limit dimensions symmetrically to the nominal geometry. Asymmetrical tolerances of size dimensions (e.g. fitting dimensions) must be converted into a symmetrical tolerance field position by formal nominal dimension modification to the tolerance center dimension: 100-0.6 → 99.7 ± 0.3.
- The verification of the part with regard to quality assurance must be clearly defined. The measuring concept is particularly important for parts that are not dimensionally stable, see also DIN ISO 10579.
- Unless otherwise agreed, moulded parts may not be automatically rejected if the general tolerances are not complied with, provided the function is not impaired.
- Constructively specified inclination differences due to draft angles are not part of dimensional tolerances or deviations in shape and position. In the specification, measurement points must be defined for function dimensions on inclined surfaces in order to define two-point dimensions.
- To specify radii, at least 90° of the circle segment must be available as a measurable contour. Alternatively, radii can be tolerated by profile shape tolerances.

- Freeform surfaces shall be specified with a profile shape tolerance. Verification shall be agreed
- Directly tolerated angles and edges are subject to agreement. All angles and edges not directly tolerated are to be neglected during verification.
- Separating crest, tool offset and their combination must be agreed with regard to the position of the separating lines between the customer and the manufacturer of the moulded parts.
- With regard to the tolerance analysis of dimensional chains, it should be noted that the usual procedures require the rigid body. For plastic moulded parts, this condition is usually not sufficiently fulfilled due to the low stiffness of the moulding material and the distortion.

scope of application

ISO 20457/DIN 16742 is used to determine production-related possible tolerances (manufacturing tolerances) and for comparison with functional tolerances in order to check the attainability of a dimensional accuracy required by the design.

Detected tolerances: Limit deviations for size dimensions (two-point dimensions) as indirect tolerance (general tolerances) and as direct tolerance (dimension given on the nominal size dimension).

For tolerating deviations in shape and position with profile shape tolerances as general tolerances and position tolerances for direct tolerance through cylindrical tolerance zones.

Process engineering basics: original moulding process with tools closed on all sides, such as injection moulding, injection embossing, injection moulding and pressing of non-porous moulded parts made of thermoplastics, thermoplastic elastomers and thermosets as well as rotational moulding of thermoplastics. For special process variants of the above-mentioned processes, the standard can be applied analogously after agreement with the molding manufacturer.

Not normatively recorded: Porous moulding materials (e.g. foams) and other processing and machining methods. The same also applies to process combinations of original forming and forming processes (e.g. injection blow molding, injection stretch molding).

Deviations from the surface quality of the molded part, such as sink marks, unwanted flow structures and roughness as well as weld lines are not the subject of the standard.

If tolerances outside the scope of the standard are required, these must be agreed with the manufacturer of the moulded part and specified in the drawing.

Definition equations for processing shrinkage

equations	explanations	
$VS = \left(1 - \frac{L_F}{L_W}\right) \cdot 100[\%]$	VS	Processing shrinkage
	L_F	Part dimensions
	L_W	Tool contour dimension
$\Delta VS = \lvert VS_\perp - VS_\parallel \rvert$	ΔVS	Absolute value of the VS difference due to shrinkage anisotropy
	$VS_\perp$	VS transverse to the direction of melt flow
	$VS_\parallel$	VS parallel to melt flow direction

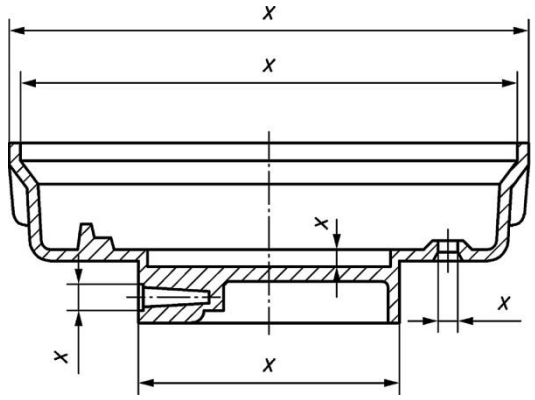
$\Delta S = VS_{max} - VS_{min}$	ΔS Scattering range (shrinkage fluctuation) of the VS VS_{max}, VS_{min} Extreme values of the VS due to the respective influencing conditions
$VS_R = 0{,}5\,(VS_{max} + VS_{min})$	VS_R Calculation value of VS, average of VS_{max} and VS_{min}

Causes and influencing factors on the processing shrinkage (VS) of non-porous plastics

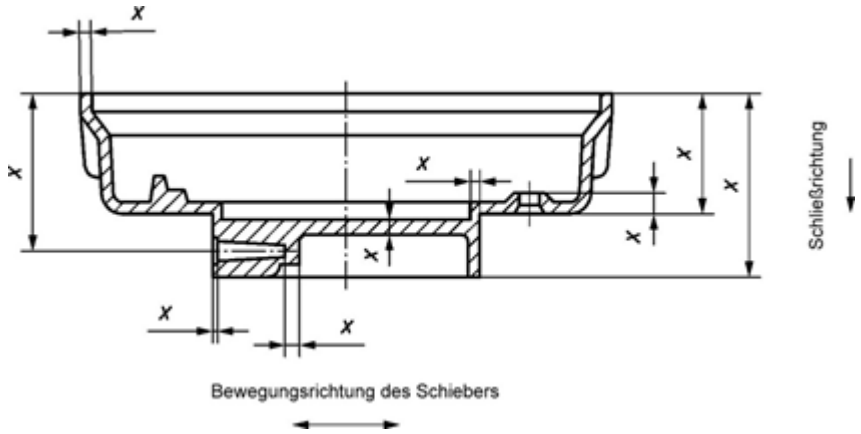
causes	Influence on processing shrinkage	
	lessening	**increasing**
Density increase due to thermal contraction by cooling the demoulding temperature to room temperature and compression by the action of pressure	• high effective pressure on moulding compound and contour until demoulding (holding pressure) • low demoulding temperature (long cooling time and/or low contour temperature) • low coefficient of thermal expansion (hard elastic polymers)	• low or prematurely reduced holding pressure until demoulding • high demoulding temperature (short cooling time and/or high contour temperature) • high coefficient of thermal expansion (soft or rubber-elastic polymers)
Density increase due to thermodynamically induced structural order processes (crystallization; gelation)	• amorphous polymers • ow degree of crystallinity of semi-crystalline polymers due to rapid solidification (subcooling due to low contour temperature and/or thin-walled parts) • high degree of gelation of polymers containing plasticizers	• semi-crystalline polymers • high degree of crystallinity due to slow solidification (high contour temperature and/or thick-walled parts) and improved nucleation (nucleation additives) • low degree of gelation of polymers containing plasticizers
Density increase due to molecular construction and cross-linking processes (curing; vulcanization; polyreaction)	• high degree of cross-linking and thus lower coefficient of thermal expansion (long curing or vulcanization time and/or high melt temperature) • Preformed or pre-crosslinked molding compounds (e.g. prepolymers)	• low degree of cross-linking and thus higher coefficient of thermal expansion (short curing or vulcanization time and/or low melt temperature) • non-crosslinked precursors (oligomers) or monomers as moulding compositions
Changes in stiffness or hardness due to additives (e.g. fillers and reinforcing materials; plasticizers)	• Additives with low coefficient of thermal expansion (e.g. inorganic fillers and reinforcing materials) • no or low plasticizer additives	• Additives with high coefficient of thermal expansion (e.g. organic fillers and reinforcing materials) • plasticizer additives

Tool binding of the moulded part dimensions

Different deformations and positional deviations of tool parts due to compressive stress are detected by differentiating between tool-bound and non-tool-bound part dimensions. Tool-related dimensions are dimensions in the same tool part, while dimensions that are not tool-related are created by the interaction of different tool parts and thus tend to cause larger dimensional variations. In addition to the rigidity of the tool design, the processing conditions have a significant influence. For the graphical demonstration of corresponding dimensions (x), a corresponding representation from ISO 20457/DIN 16742 was adopted.



Tool-related dimensions



Non-tool-related dimensions

Testing and structuring of the stiffness/hardness level of polymers without solid additives

hardness grade	E in N/mm²	Shore hardness	IRHD	Polymers
hard	> 5000 to 20000	—	—	LCP (self-reinforcing molecular anisotropy)
	> 1200 to 5000	>75 D	—	Tough to brittle hard thermoplastics, thermosets, hard rubber
semi-hard	> 300 to 1200	> 60 to 75 D	—	Elastomer-like (soft-elastic) thermoplastics,

	> 30 to 300	> 35 to 60 D	—	thermoplastic elastomers and rubber with different degrees of hardness
soft	3 to 30	50 to 90 A	50 to 90	
extremely soft	< 3	< 50 A	< 50	
E: E-module of origin from the short-time tensile test according to DIN EN ISO 527 Shore hardness: Penetration hardness according to DIN EN ISO 868 (Methods A and D) IRHD: International rubber hardness (ball indentation hardness) according to DIN EN ISO 48				All tests are carried out at 23 °C and with normal conditioned test specimens.
– Steel for comparison: E = 200 000 N/mm² – Filled or reinforced polymers can be assigned with their modulus of elasticity.				

Notes on the classification of tolerance groups according to process and moulding compound

- To classify the process, it can only be stated that "spraying processes" allow a higher production accuracy than pressing processes.
- The classification of moulding material stiffness and hardness is unproblematic, as corresponding data are always available (moulding material manufacturers, databases). The classification of cross-border data is at the discretion of the user.
- The classification of the expected calculation value of the processing shrinkage should be agreed with the manufacturer of the moulded part, if no own experience is available. A detailed compilation of guide values is available in the programme as a guide.
- The assessment of the expected fluctuations in shrinkage may be problematic as a result of many influencing factors. This is where the moulded part manufacturer can be expected to provide the most effective help. In case of doubt, "only inaccurately possible" should be entered in order to consider further processing by means of a more precise tolerance series if necessary. ISO 20457/DIN 16742 specifies the following aids for classification:
    - **Exactly possible**: Calculated values of the VS are known, e.g. from experience, systematic measurements, computer simulations. Shrinkage anisotropy is insignificant or can be sufficiently accurately considered in the respective dimensional direction. Possible deviations from the calculated value are max. ± 10 %.
    - **Accurately possible**: Calculated values are known in ranges up to ± 20 %.
    - **Only inaccurately possible**: Calculated values of the VS are only known as rough guide value ranges. Shrinkage anisotropy cannot or only insufficiently be considered. Practical experience for estimating relevant calculation values is not available. Possible deviations from the calculated value are above ± 20 %.

In agreement with the users of rotational moulding of thermoplastics, the tolerance group TG9

was defined for this process.

For multicomponent parts, the tolerance group must be determined for each material and specified as a separate general tolerance (e.g. hard component according to TG5, soft component according to TG7). The more inaccurate material is the basis for defining tolerances for all material sizes.

Nominal sizes definitions

Nominal size dimensions (linear dimensions, two-point dimensions) for limit deviations according to Table 2 of ISO 20457/DIN 16742 are tolerance center dimensions for drawings and CAD data sets.

D_P-Dimmensions (distance dimensions) according to ISO 20457/DIN 16742 are nominal dimensions for position tolerances according to Table 9 and for profile shape tolerances according to Table 10 with the following definition:

> *„A component can have one or more reference systems. To determine the profile shape and position tolerance, the longest distance of the tolerated element to the origin of the reference system (D_P dimension) used for profile shape and position tolerance shall be used. This does not have to match the coordinate system of the part or assembly.“*

An example of position tolerance is given in Appendix G of ISO 20457/DIN 16742.

For tolerating the distance of parallel surfaces which are not directly opposite each other but are arranged offset from each other, the D_P dimension for limit dimensions according to Table 9 of ISO 20457/DIN 16742 is provided as the nominal size dimension. Furthermore applies:

- Nominal dimensions below 1 mm and above 1000 mm are subject to agreement.
- For general tolerances, only the limit dimensions for moulded part dimensions that are not tool-bound apply.
- Limiting dimensions for wall thicknesses are subject to agreement.
- General tolerances shall be specified in the design documentation as follows: Example: DIN 16742 – TG6.

Dimensional reference planes, causes of dimensional changes and moulded part acceptance conditions

The dimensional variation in the application and production of plastic moulded parts requires the consideration of three closely connected dimensional reference planes: **Parts application**, **parts production**, **tool production**. For the dimensional reference planes, different physical causality relationships must be observed and systematically merged, whereby the design of the construction is to be processed mentally in the opposite direction to the direction of dimension formation. The principle of different dimensional reference planes is also clearly explained in DIN 16742 (Annex A).

Figure 1 shows the dimensional quantities and dimension relationships with respect to position (center of tolerance dimension C), displacement (offset Δl), and dispersion (tolerance T) for the dimensional reference planes. The direction of the dimensional displacement is taken into account by sign.

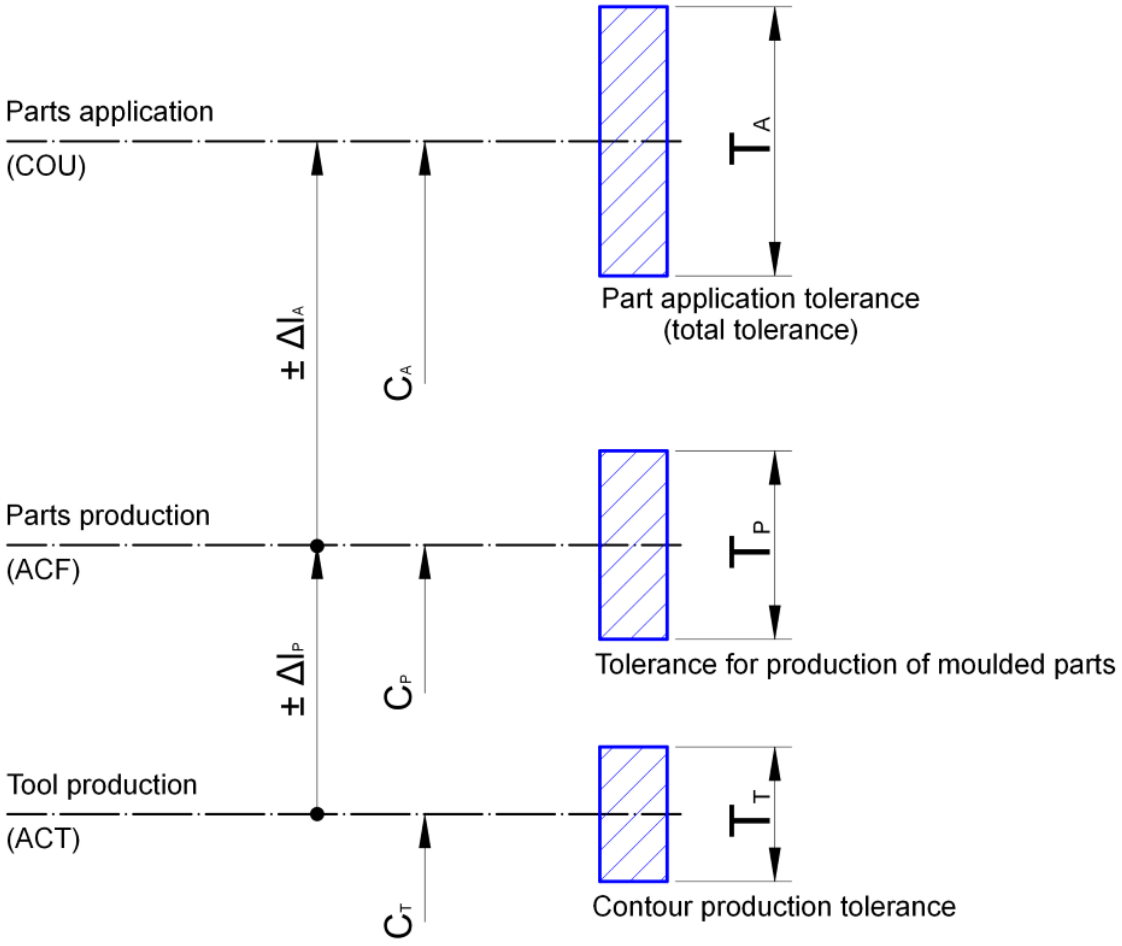


Figure 1: Dimensional reference planes for application and production of plastic parts

Conditions of use (COU): All conditions of use and storage of the parts during the period of use after manufacture, provided that they affect the dimensional accuracy and functional performance of the products.

If assembly or completion of the individual parts to form assemblies only takes place in longer periods after the parts have been manufactured, the parts storage and completion conditions may have to be treated as a special case by the COU. For soft or rubbery moulding materials, the influence of the COU can often be neglected. The same applies to assemblies made of completely identical materials. In each individual case, however, the COU must be determined depending on the situation and function. For the part user, the recording of the company-specific COU and its influence on dimensional accuracy is a useful rationalization tool. A general compilation or standardization of all COU is not possible due to the large number and complexity of the influences.

Cause factors of the application-related dimensional change (all relevant factors are summarised in groups below):

- Climate effects due to ambient temperatures, humidity, precipitation and solar radiation,
- Energy effects caused by heat sources and high-energy radiation,
- Diffusion contact with vapours and liquids as well as migration contact with solids,
- Material removal (wear) due to friction, cavitation and erosion as well as biological influences,
- Mechanical deformation by external forces and moments as well as by relaxation of internal stresses,

- Molecular and micromorphological material structure transformations.

Causes for length deviations due to production:

- Scattering of processing shrinkage depending on moulding compound and production,
- Uncertainties in the determination of calculated values of the processing shrinkage for tool contour calculation, especially with large shrinkage values and with shrinkage anisotropy,
- Different reshaping behaviour of the parts after demoulding, depending on the stiffness or hardness of the moulding material,
- Production-related dimensional variation of the tool contours including hardness distortion and surface coating,
- Deformations and positional deviations of tool parts due to compressive stress,
- Tool contour wear.

Causes of moulding distortion: Distortion (warping, twisting, warping) is the physical cause of deviations in shape, position and angle of the plastic moulded parts. It is caused by local and direction-dependent shrinkage differences (shrinkage anisotropy) and at extreme post- or compression pressure by re-deformation (relaxation) of elastic residual stresses. In principle, distortion of molded parts cannot be avoided, but can be minimized (Chapter 5).

Acceptance conditions for the production of fittings (ACF): For normative acceptance conditions according to ISO 20457/DIN 16742 and DIN EN ISO 219, the test dimensions are considered acceptance values if the fittings are stored at 23 °C ± 2 K and 50 % ± 10 % relative humidity after production until acceptance and are tested at the earliest 16 h and at the latest 72 h after manufacture.

In case of deviations from the normative ACF, the acceptance parameters for the control dimension test according to ISO 20457/DIN 16742 must be agreed and documented separately between manufacturer and customer:

- Dimensional position and deviations (if necessary after testing),
- Dimensional inspection procedures,
- Minimum and maximum period of dimensional inspection after parts production,
- Storage and test conditions until parts are removed (room air temperature, relative air humidity, special storage regulations if necessary).

Deviations from the normative ACF can be:

- Subsequent operations at the parts manufacturer with material application (painting, coating) or material removal (machining, grinding, polishing),
- Post-treatment of parts by tempering (anticipation of post-shrinkage, compensation of internal stresses, post-hardening) or subsequent operations with significant thermal stress on parts (painting, solder bath treatment, etc.)

- Partial after-treatment by conditioning, e.g. by watering (anticipation of swelling, increase in toughness),
- Low dimensional stability of the structure and condition of the moulding material at ACF. Examples are structural changes in the crystalline phase of semi-crystalline polymers (e.g. PB) and swelling as well as softening due to water absorption of thin-walled molded parts made of hydrophilic polymers (e.g. PA6, PA66, PA46, biopolymers).

Acceptance conditions for tool production (ACT): The control dimensions of the tool contours determined by testing are considered acceptance values at a reference temperature of 23 °C ± 2 K. They include hardening distortion.

Notes on the classification of the tolerance series

According to ISO 20457/DIN 16742, the realization of the required level of accuracy in the production of moulded parts requires an assignment to the tolerance series:

Series 1 (standard production): Production with general tolerances may be possible. Dimensional requirements are not a particular focus of quality.
Series 2 (precise production): Production and quality assurance are oriented towards higher dimensional accuracy requirements.
Series 3 (precision production): Complete alignment of production and quality assurance to the very high dimensional accuracy requirements
Series 4 (special precision production): Same as series 3, but with intensified process monitoring.
Tolerance series 3 and 4 are always subject to agreement

Only absolutely necessary small functional tolerances justify the production costs of series 3 and 4, which must be compensated for with a significant surcharge. Therefore, it must first be clarified between the customer and the manufacturer whether the tolerance requirements can be met. Self-deceptions are bad advisors for all cooperation partners. The following conditions should be checked with appropriate expertise:

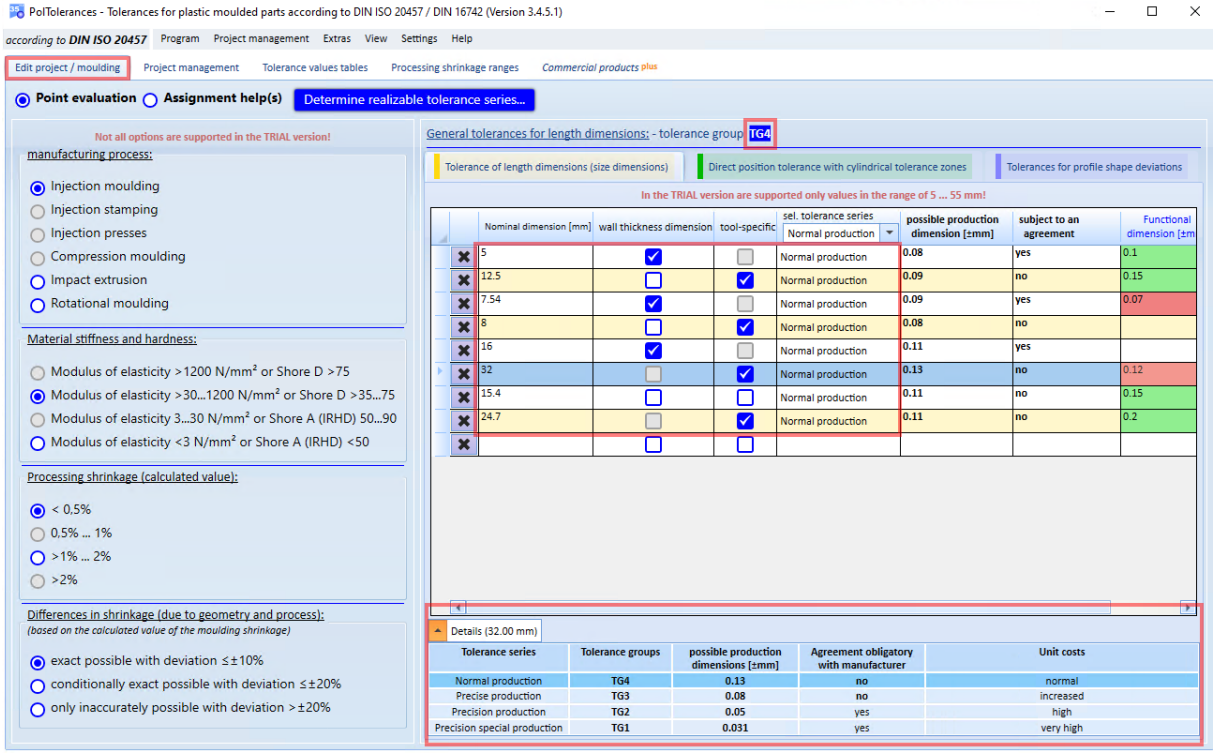
- Dimensionally accurate design and dimensioning of the moulded part.
- Functional safety of tools that are sufficiently rigid and thermally and rheologically balanced.
- Operation of necessary machines and systems by sufficiently qualified operating personnel including quality assurance.
- Delivery conditions of the molding compounds with regard to dimensionally relevant properties, in particular fluctuations in shrinkage.

To support the assignment of the tolerance series, selection criteria for thermoplastic injection moulding are listed in Appendix D of DIN 16742 as examples. These selection criteria are taken into account internally by an extended selection algorithm.

How to use

We have published a corresponding YouTube video for a quick introduction to how to use the software. You can find the link to the video on our website in the description of the respective software product.

Measurements input

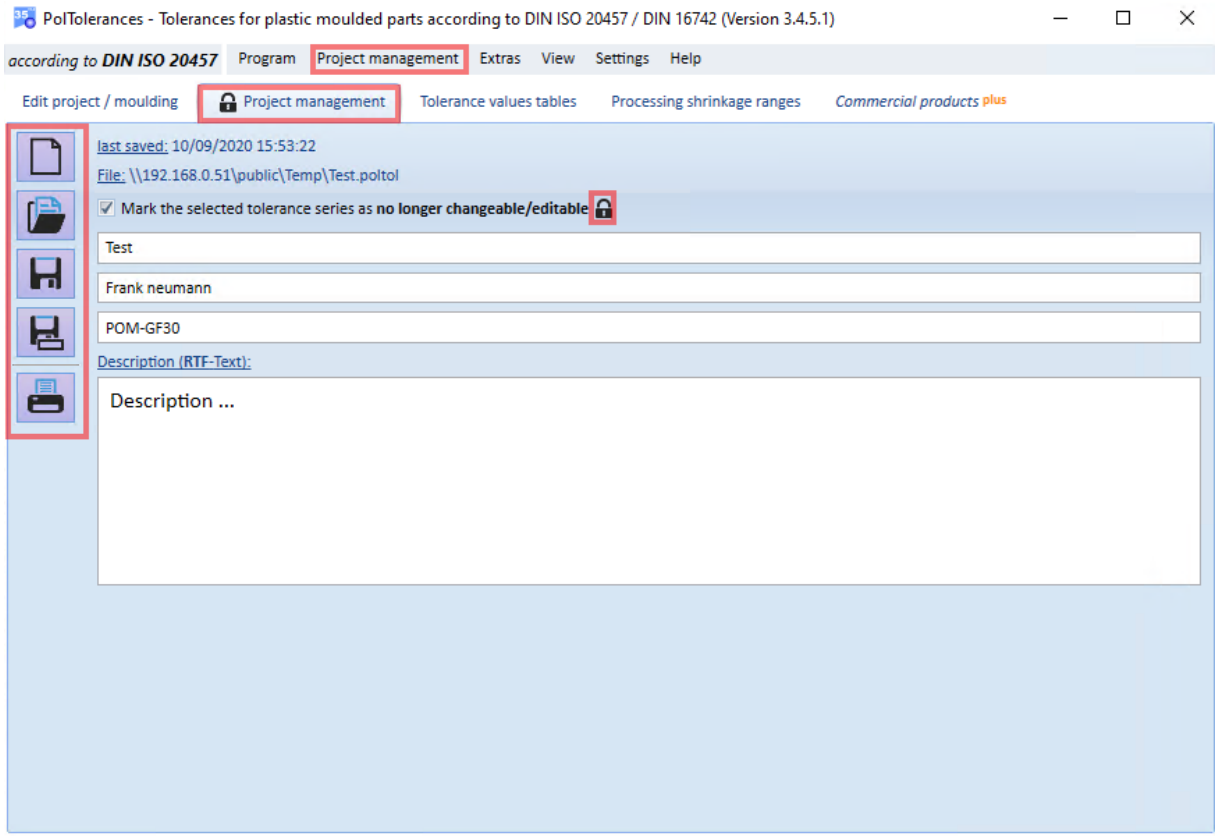


1. select the corresponding tab (here: *Tolerance of length dimensions*).
2. Enter the corresponding dimension in the first column
3. if necessary, enter additional data for the respective dimension (here in columns 2-4)
4. the tolerance series can be specified superordinately for all dimensions by selecting it in the selection box of the column heading
5. as soon as also all inputs/decisions for the evaluation method (*point evaluation* and/or *assignment help(s)*) are available, the results per measurement are immediately displayed/updated (here: in the columns *possible functional dimension* and *subject to agreement*)
6. If you have also entered information on the functional dimension, the possible production dimension is compared with the functional dimension. If the required functional dimension is greater than or equal to the possible production dimension, the corresponding cell in the table is highlighted in **green** (otherwise it is highlighted in **red**).

If you select an entry in the table, further details about this dimension are displayed below the table.

Please note that in the **TRIAL version** only dimensions in a restricted value range can be entered.

Project management



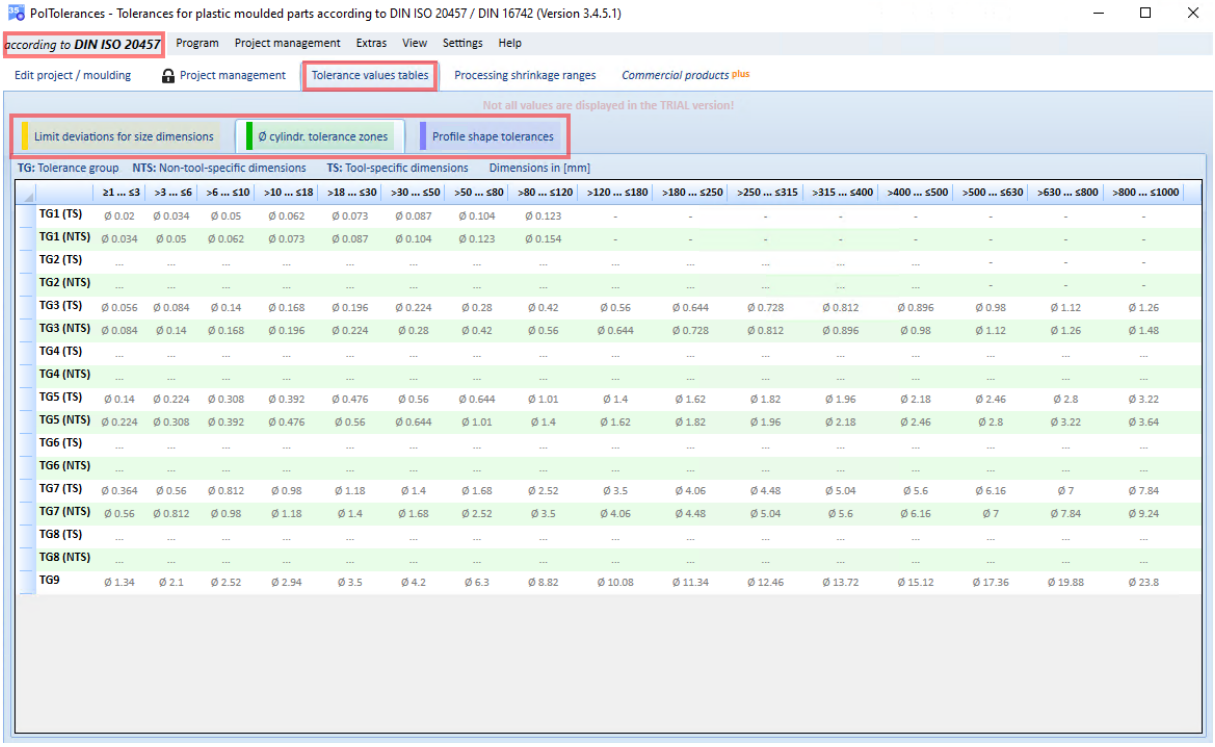
- you can manage all inputs and decisions in individual project files.
- As a rule, a project file considers a single molded part to be toleranced.

The following functions are available for selection and can be called up via the buttons shown or the corresponding menu items:

1. create new project. Your previous data will be lost
2. load an existing project. Your previous data will be lost.
3. save the current data. At least one project name must be entered to be able to save the project as a file.
4. save the current data under another file (file name)
5. display the entries and results in a print preview and print them out

Furthermore, you can protect certain decisions against accidental editing by setting the corresponding checkmark "*Mark selected tolerance series as no longer changeable/editable*". This edit protection is additionally highlighted by a corresponding symbol and saved in the project file.

Tolerance values tables



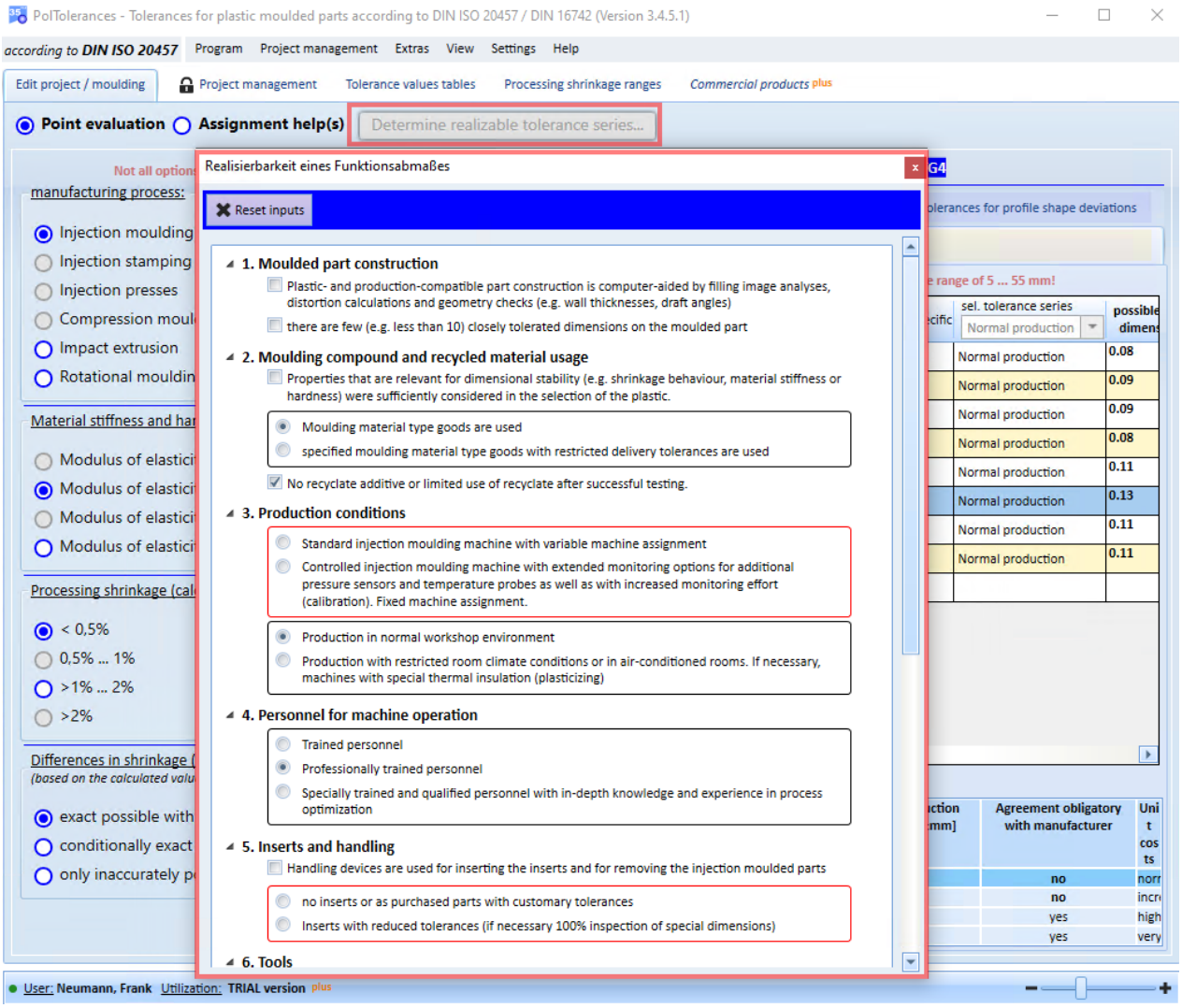
	≥1 … ≤3	>3 … ≤6	>6 … ≤10	>10 … ≤18	>18 … ≤30	>30 … ≤50	>50 … ≤80	>80 … ≤120	>120 … ≤180	>180 … ≤250	>250 … ≤315	>315 … ≤400	>400 … ≤500	>500 … ≤630	>630 … ≤800	>800 … ≤1000
TG1 (TS)	Ø 0.02	Ø 0.034	Ø 0.05	Ø 0.062	Ø 0.073	Ø 0.087	Ø 0.104	Ø 0.123	-	-	-	-	-	-	-	-
TG1 (NTS)	Ø 0.034	Ø 0.05	Ø 0.062	Ø 0.073	Ø 0.087	Ø 0.104	Ø 0.123	Ø 0.154	-	-	-	-	-	-	-	-
TG2 (TS)	...	...	...	...	...	...	...	...	...	...	...	...	...	-	-	-
TG2 (NTS)	...	...	...	...	...	...	...	...	...	...	...	...	...	-	-	-
TG3 (TS)	Ø 0.056	Ø 0.084	Ø 0.14	Ø 0.168	Ø 0.196	Ø 0.224	Ø 0.28	Ø 0.42	Ø 0.56	Ø 0.644	Ø 0.728	Ø 0.812	Ø 0.896	Ø 0.98	Ø 1.12	Ø 1.26
TG3 (NTS)	Ø 0.084	Ø 0.14	Ø 0.168	Ø 0.196	Ø 0.224	Ø 0.28	Ø 0.42	Ø 0.56	Ø 0.644	Ø 0.728	Ø 0.812	Ø 0.896	Ø 0.98	Ø 1.12	Ø 1.26	Ø 1.48
TG4 (TS)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
TG4 (NTS)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
TG5 (TS)	Ø 0.14	Ø 0.224	Ø 0.308	Ø 0.392	Ø 0.476	Ø 0.56	Ø 0.644	Ø 1.01	Ø 1.4	Ø 1.62	Ø 1.82	Ø 1.96	Ø 2.18	Ø 2.46	Ø 2.8	Ø 3.22
TG5 (NTS)	Ø 0.224	Ø 0.308	Ø 0.392	Ø 0.476	Ø 0.56	Ø 0.644	Ø 1.01	Ø 1.4	Ø 1.62	Ø 1.82	Ø 1.96	Ø 2.18	Ø 2.46	Ø 2.8	Ø 3.22	Ø 3.64
TG6 (TS)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
TG6 (NTS)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
TG7 (TS)	Ø 0.364	Ø 0.56	Ø 0.812	Ø 0.98	Ø 1.18	Ø 1.4	Ø 1.68	Ø 2.52	Ø 3.5	Ø 4.06	Ø 4.48	Ø 5.04	Ø 5.6	Ø 6.16	Ø 7	Ø 7.84
TG7 (NTS)	Ø 0.56	Ø 0.812	Ø 0.98	Ø 1.18	Ø 1.4	Ø 1.68	Ø 2.52	Ø 3.5	Ø 4.06	Ø 4.48	Ø 5.04	Ø 5.6	Ø 6.16	Ø 7	Ø 7.84	Ø 9.24
TG8 (TS)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
TG8 (NTS)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
TG9	Ø 1.34	Ø 2.1	Ø 2.52	Ø 2.94	Ø 3.5	Ø 4.2	Ø 6.3	Ø 8.82	Ø 10.08	Ø 11.34	Ø 12.46	Ø 13.72	Ø 15.12	Ø 17.36	Ø 19.88	Ø 23.8

In this view, you can display the tolerance values that are used for calculation/evaluation, among other things.

The values displayed depend on the selected standard ***DIN ISO 20457*** or ***DIN 16742***.

Note that not all values are displayed in the TRIAL version.

Determine realizable tolerance series



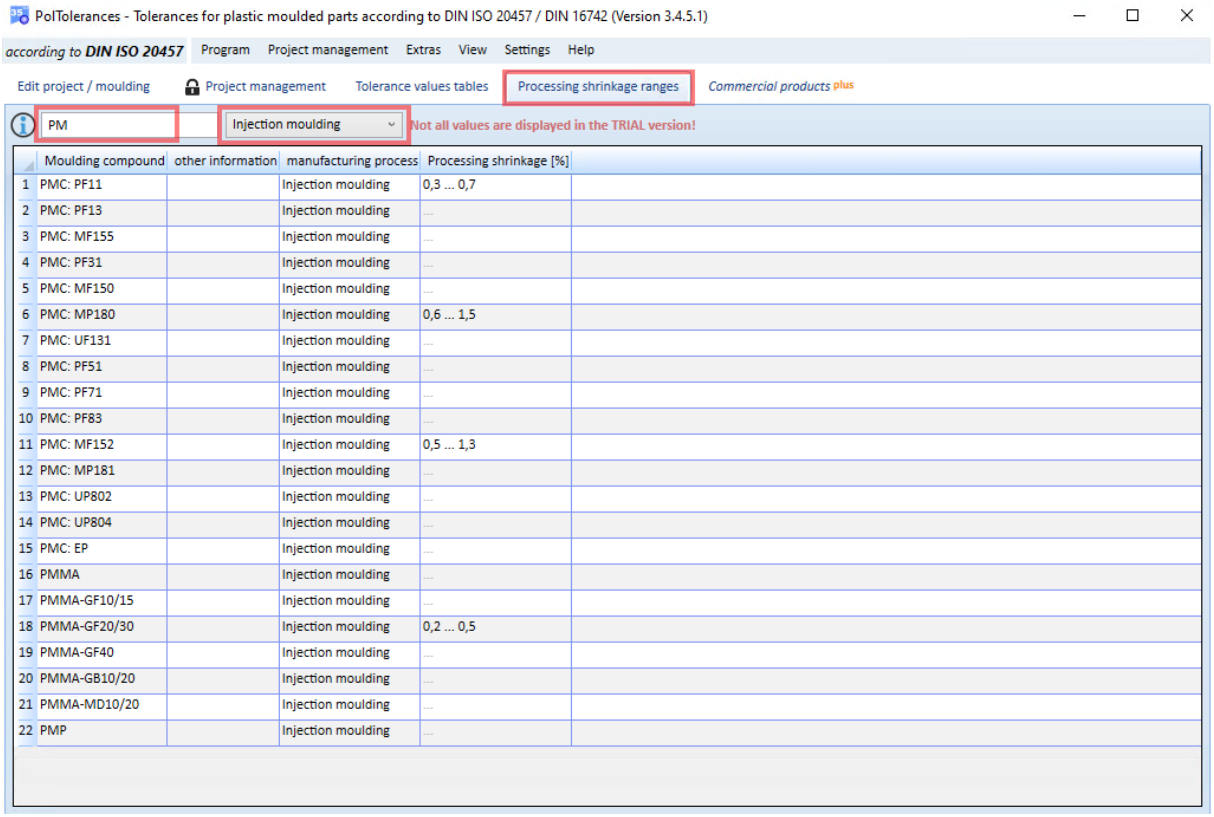
We have additionally provided a function with which you can determine the realizable tolerance series.

In the main window you will find the button [*Determine realizable tolerance series*]. If you click this, a further window is opened.

If you have made a corresponding decision/selection for each aspect, the result is displayed at the top (to the right of the [*Reset inputs*] button). You can correct your entries at any time. All entries/decisions made here are also output in the print log.

Decisions that are still open are shown with a red border.

Processing shrinkage ranges



	Moulding compound	other information	manufacturing process	Processing shrinkage [%]
1	PMC: PF11		Injection moulding	0,3 ... 0,7
2	PMC: PF13		Injection moulding	...
3	PMC: MF155		Injection moulding	...
4	PMC: PF31		Injection moulding	...
5	PMC: MF150		Injection moulding	...
6	PMC: MP180		Injection moulding	0,6 ... 1,5
7	PMC: UF131		Injection moulding	...
8	PMC: PF51		Injection moulding	...
9	PMC: PF71		Injection moulding	...
10	PMC: PF83		Injection moulding	...
11	PMC: MF152		Injection moulding	0,5 ... 1,3
12	PMC: MP181		Injection moulding	...
13	PMC: UP802		Injection moulding	...
14	PMC: UP804		Injection moulding	...
15	PMC: EP		Injection moulding	...
16	PMMA		Injection moulding	...
17	PMMA-GF10/15		Injection moulding	...
18	PMMA-GF20/30		Injection moulding	0,2 ... 0,5
19	PMMA-GF40		Injection moulding	...
20	PMMA-GB10/20		Injection moulding	...
21	PMMA-MD10/20		Injection moulding	...
22	PMP		Injection moulding	...

Information on the processing shrinkage of plastics/molding compounds is important for the evaluation and thus for the determination of tolerance values or possible production dimensions.

The database currently contains approx. **430 processing shrinkage ranges** for different plastics/molding compounds and for the following manufacturing processes

- Injection molding
- Injection pressing
- compression molding
- Impact extrusion

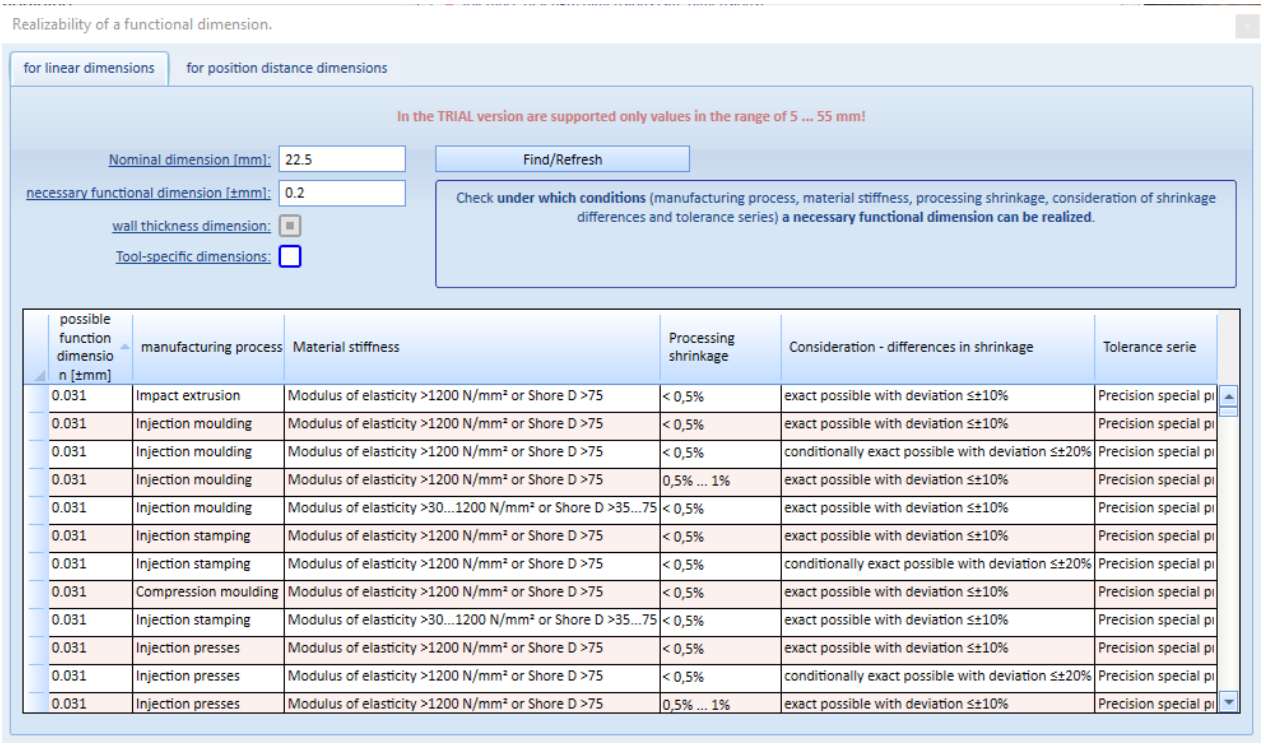
are included.

The upper text box or the selection box can be used to filter by molding compounds and/or manufacturing processes.

Please note that not all values are displayed in the TRIAL version.

Feasibility of required functional dimensions

The software contains functions to determine under which conditions a certain functional dimension can be realized.



possible function dimension [±mm]	manufacturing process	Material stiffness	Processing shrinkage	Consideration - differences in shrinkage	Tolerance serie
0.031	Impact extrusion	Modulus of elasticity >1200 N/mm² or Shore D >75	< 0,5%	exact possible with deviation ≤±10%	Precision special pı
0.031	Injection moulding	Modulus of elasticity >1200 N/mm² or Shore D >75	< 0,5%	exact possible with deviation ≤±10%	Precision special pı
0.031	Injection moulding	Modulus of elasticity >1200 N/mm² or Shore D >75	< 0,5%	conditionally exact possible with deviation ≤±20%	Precision special pı
0.031	Injection moulding	Modulus of elasticity >1200 N/mm² or Shore D >75	0,5% ... 1%	exact possible with deviation ≤±10%	Precision special pı
0.031	Injection moulding	Modulus of elasticity >30...1200 N/mm² or Shore D >35...75	< 0,5%	exact possible with deviation ≤±10%	Precision special pı
0.031	Injection stamping	Modulus of elasticity >1200 N/mm² or Shore D >75	< 0,5%	exact possible with deviation ≤±10%	Precision special pı
0.031	Injection stamping	Modulus of elasticity >1200 N/mm² or Shore D >75	< 0,5%	conditionally exact possible with deviation ≤±20%	Precision special pı
0.031	Compression moulding	Modulus of elasticity >1200 N/mm² or Shore D >75	< 0,5%	exact possible with deviation ≤±10%	Precision special pı
0.031	Injection stamping	Modulus of elasticity >30...1200 N/mm² or Shore D >35...75	< 0,5%	exact possible with deviation ≤±10%	Precision special pı
0.031	Injection presses	Modulus of elasticity >1200 N/mm² or Shore D >75	< 0,5%	exact possible with deviation ≤±10%	Precision special pı
0.031	Injection presses	Modulus of elasticity >1200 N/mm² or Shore D >75	< 0,5%	conditionally exact possible with deviation ≤±20%	Precision special pı
0.031	Injection presses	Modulus of elasticity >1200 N/mm² or Shore D >75	0,5% ... 1%	exact possible with deviation ≤±10%	Precision special pı

To do this, open the corresponding menu item in the "Extras" menu.

A window then opens in which you enter the nominal size dimension and the required functional dimension. You must also make decisions about the wall thickness dimension and whether it is a tool-bound or non-tool-bound dimension.

As soon as all entries are complete, you can start the function using the [Find/Refresh] button. If results are found that are smaller than or equal to the required functional dimension, this is displayed in the list (below the input).

The list can be sorted by the individual columns.