PolCycleTime

Cooling, cycle and conditioning time calculation as well as price and demand calculations

User Manual

Cycle time · Price and demand calculation · Conditioning time

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1 Introduction

PolCycleTime supports you in planning injection moulded parts, from the first cost estimate to post-treatment. The software contains three modules, which you reach via the tabs on the left edge of the window:

- **Cooling and cycle time calculation:** cooling time and cycle time of a moulded part from moulding compound, mould, demoulding and geometry (chapter 3).
- **Price and demand calculations:** unit costs, mould demand, optimum number of cavities, machine utilization, machine hourly rate and lot size, also as a comparison of several variants (chapter 4).
- **Calculation of conditioning times:** time until polyamide parts reach the desired moisture content for use (chapter 5).

In addition, the **“Calculation modules”** menu contains a stand-alone auxiliary calculation for the melt density (chapter 6).

All results are recalculated immediately after every change. As long as data is missing, the program shows the message **“Inputs and decisions are still missing.”**

> **Note:** The **“Commercial products plus”** tab is not described in this manual. There is a separate manual for the commercial products.

2 User interface

The figure shows the **Cooling and cycle time calculation** module with a fully calculated example.

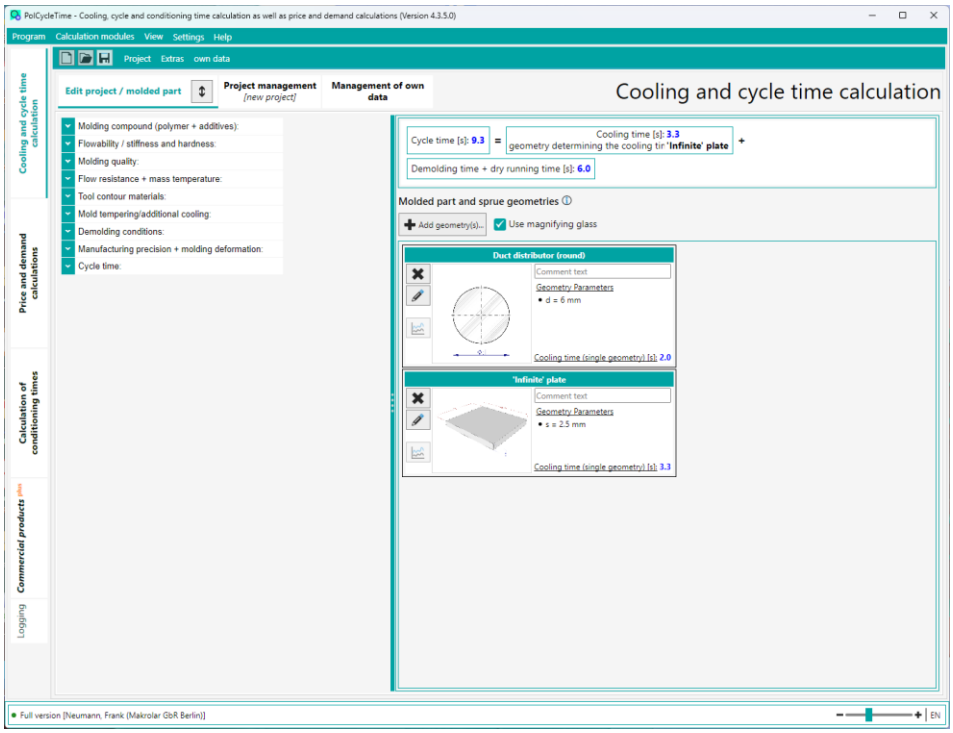


Figure 1: Main window with the cooling and cycle time calculation

Element	Meaning
Menu bar	**“Program”**, **“Calculation modules”**, **“View”**, **“Settings”** and **“Help”** (chapter 7).

Element	Meaning
Tabs on the left edge	Switch between **Cooling and cycle time calculation**, **Price and demand calculations** and **Calculation of conditioning times**.
Module bar	Icons **New**, **Open**, **Save** and the module menus (e.g. **“Project”**, **“Extras”**, **“own data”**).
Tab **“Edit project / moulded part”**	Inputs on the left in collapsible sections, results on the right. The button with the double arrow expands or collapses all sections.
Tab **“Project management”**	New project, load, save, save as and print; also project name, processor and description. The project name is shown below the tab title.
Tab **“Management of own data”**	Own polymers, additives, injection moulding machines or material data.
Status bar	License status, zoom slider and language of the user interface (“EN”).

Tip: You can move the splitter between inputs and results with the mouse.

3 Cooling and cycle time calculation

The module determines the **cooling time** of each moulded part and sprue geometry and from this the **cycle time** of the moulded part. The example used throughout is an **ABS cover plate** with a wall thickness of 2.5 mm, filled via a round runner with a diameter of 6 mm and removed by a handling device.

The program estimates the cooling and cycle time for standard injection moulding of non-porous thermoplastics and thermoplastic elastomers. It can be applied analogously to special variants of the injection moulding process, although the accuracy may then be somewhat lower. Typical applications are:

- presetting of the machine
- preliminary cost calculation
- production lead time planning
- heat balances
- input data for process simulation

To minimize the cycle time, a systematic optimization under real production conditions is usually recommended. Because cycle time breakdowns are handled differently in practice, the program uses the following definitions:

Term	Definition
Cooling time	Time from the start of mould filling until the moulded part is demoulded, i.e. the physically effective total time for cooling the moulding compound in the mould.
Cycle time	Cooling time plus the demoulding time of the moulded part and the dry running time (idle time) of the machine.

The cooling time calculation is based on analytical solutions of transient heat transfer, which have been considerably extended and modified for the specific conditions.

3.1 Working method

The **“Edit project / moulded part”** tab is divided into two parts: on the left are the inputs in collapsible sections (expanders), on the right the **moulded part and sprue geometries** with the results above them. Work through the sections on the left **from top to bottom**, then create the geometries with their dimensions on the right.

- As long as inputs or decisions are missing in a section, its **heading is red**. When everything has been entered, it turns black.
- The yellow bar at the top reports **“Inputs and decisions are still missing.”** until all data is complete. Only then do the results appear.
- Some check boxes have three states. A filled square means **“not yet decided”**; click until the box is empty (no) or ticked (yes).
- The button with the double arrow next to the tab title expands or collapses all sections.

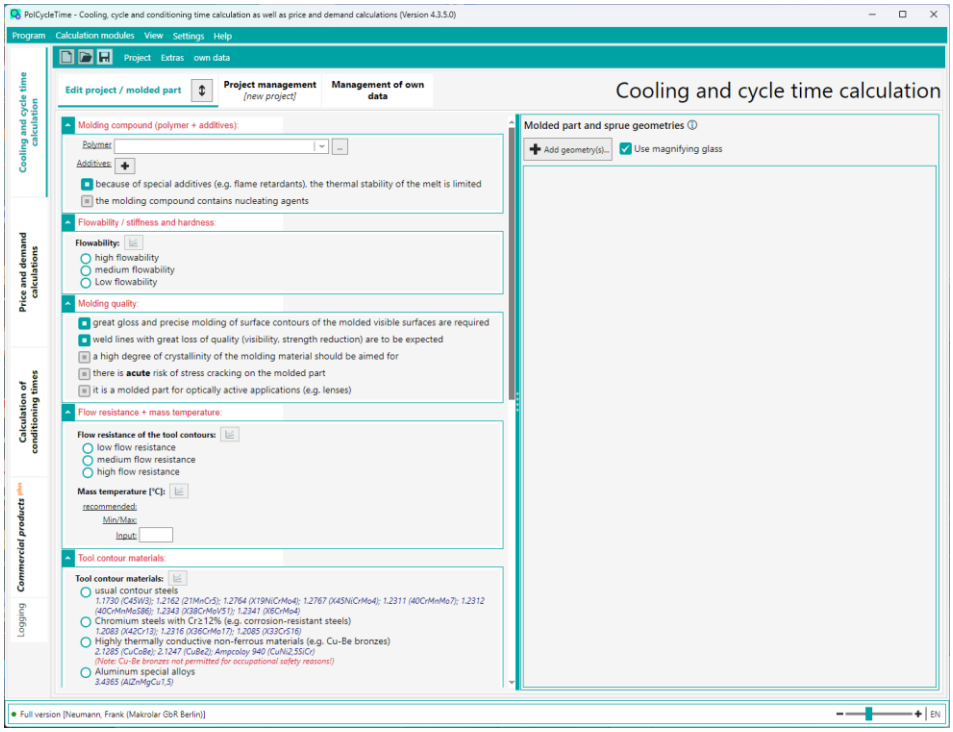


Figure 2: New project: all section headings are still red

> **Note:** The order is not mandatory; results appear as soon as all data is available. Working from top to bottom is nevertheless recommended, because the information for later inputs partly builds on earlier decisions. Create a separate project file for each moulded part or each combination of moulded part, mould and machine.

3.2 Moulding compound, flowability and moulding quality

- **Moulding compound (polymer + additives):** select the **Polymer** from the list (ABS in the example). Use **“+”** to add additives such as glass fibers with their mass fraction. Decide whether the thermal stability of the melt is limited by special additives (e.g. flame retardants) and whether the moulding compound contains nucleating agents.
- **Flowability / stiffness and hardness:** high, medium or low flowability of the moulding compound (medium in the example).

- **Moulding quality:** special requirements such as high gloss, weld lines with loss of quality, a high degree of crystallinity, risk of stress cracking or optically active applications. None of them applies in the example; all boxes remain empty.

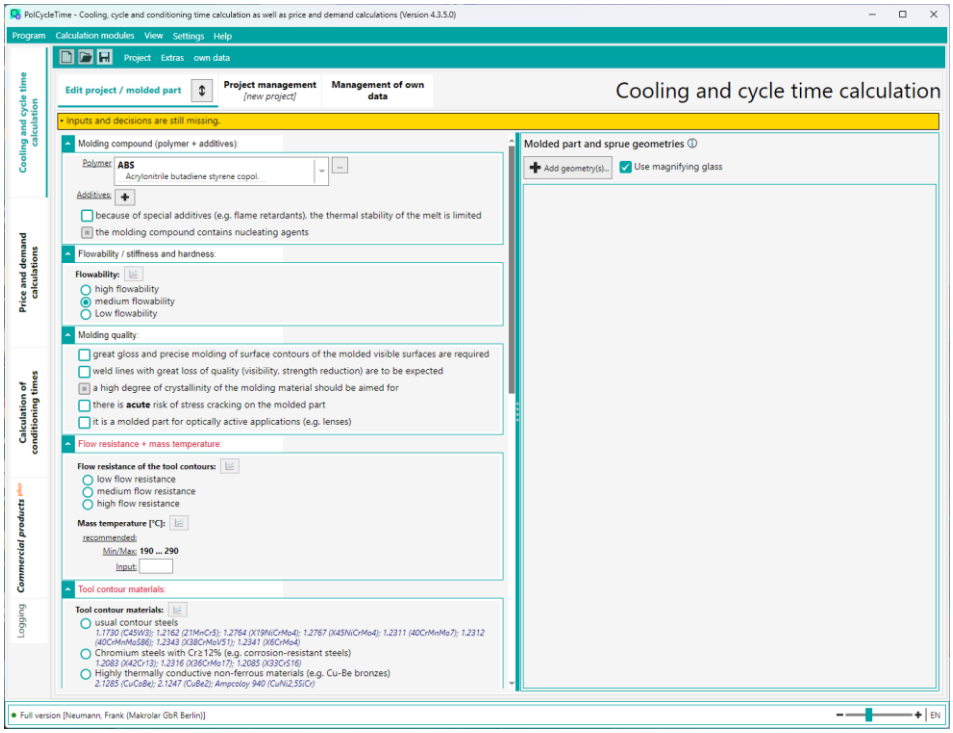


Figure 3: Moulding compound, flowability and moulding quality completed

Moulding compound and additives. Polymers without additives and the additives are identified by abbreviation and name according to EN ISO 1043, DIN EN ISO 18064 and ISO 1874. Density ranges of the polymers (at 23 °C, without flame retardants) serve as an additional aid for the assignment; in some cases characteristic properties (e.g. density, Shore hardness, heat deflection temperature) are given to distinguish between types. Because of its solid consistency and the fact that it does not melt (powder, flakes), PTFE is treated as an additive, not as a blend component. Biodegradable or compostable polymers in the sense of DIN EN ISO 14885 and DIN EN ISO 13432 are marked with “bioab” at the beginning of the name. Up to five additives can be specified; if necessary, the supplier of the moulding compound must disclose their type and mass fraction.

Flowability. The relative flowability within a range of moulding compounds is the fluidity graded by rheological test values. Thermoplastic melts are shear-thinning (pseudoplastic) and viscoelastic media whose viscosity depends on temperature as well as on shear and elongational stress. In simplified form, the flow behavior is characterized by single-point data, usually the melt volume-flow rate (MVR) or melt mass-flow rate (MFR) according to ISO 1133. Since different test conditions apply to each polymer type, different polymers cannot be compared; however, the manufacturers rate the flow behavior within their own range (e.g. easy flow, standard flow, high viscosity). **Stiffness and hardness** are quantified by the initial modulus of elasticity from the short-term standard tests (tension, bending, compression) and by the Shore hardness according to DIN EN ISO 868 (methods A and D) or the ball indentation hardness according to DIN ISO 48 (IRHD).

Moulding quality. Notes on the individual requirements:

- **Gloss:** smooth part surfaces require an appropriate finish or polish of the mould contours; for textured visible surfaces, pay particular attention to the fine structures.

- **Weld lines:** whether they occur can be clarified by geometric considerations (fountain flow) or a filling simulation. Whether the loss of quality (visibility, strength) is acceptable must be decided according to the requirements and experience.
- **A high degree of crystallinity** of semi-crystalline polymers results, among other things, in higher stiffness and heat resistance, better chemical and wear resistance and lower post-shrinkage, at the cost of higher moulding shrinkage.
- **Stress cracking:** abrupt cooling creates internal tensile stresses that cause crazing in brittle plastics (e.g. PS) or stress cracking under the influence of media; the same applies to overmoulding metal or ceramic inserts that have not been preheated. Amorphous, stiff thermoplastics are particularly at risk; their critical strain for crack formation can be well below 1 % (PS: crazing already below 0.3 % strain). Higher contour temperatures reduce the residual stresses; ask the moulding compound manufacturers or consult the literature to find out which media are critical.
- **Optically active parts** (e.g. lenses, mostly made of acrylic polymers) require very low residual stresses and a long holding pressure phase. For these, the program specifies high contour temperatures just below the glass transition temperature. Select the “plate” or “shell” geometry with a mean wall thickness estimated from the radii of curvature.

The surface quality of the mould contours is graded by the arithmetic mean roughness Ra according to DIN EN ISO 4287:

Surface	Mean roughness Ra
technically rough (no finishing)	≥ 3 µm
smooth (finishing, e.g. grinding)	0.8 … 1.6 µm
glossy (coarse polish)	0.2 … 0.4 µm
high gloss (fine polish)	0.05 … 0.10 µm
mirror finish (optical superfine polish)	0.012 … 0.025 µm

As the polish quality increases, the costs of manufacturing and maintaining the moulds rise considerably, while the replication accuracy on the part surface decreases. Mirror-finish surfaces should therefore only be used for transparent plastics with special requirements (e.g. lenses, scales).

3.3 Flow resistance, tool contour materials and mould tempering

- **Flow resistance + mass temperature:** low, medium or high flow resistance of the tool contours and the **Mass temperature** (melt temperature). The program shows the recommended and the permissible range for the selected polymer (ABS: recommended 190 … 240 °C, 200 °C in the example).
- **Tool contour materials:** usual contour steels, chromium steels, highly thermally conductive non-ferrous materials, aluminum special alloys or hard nickel, each with examples of materials.
- **Mould tempering/additional cooling:** first decide whether an uneven part surface is acceptable in favor of a shorter cooling time (intensive cooling down to 20 °C). Then the **Contour temperature** field (mould wall temperature) appears with its recommended range (ABS: 30 … 60 °C, 40 °C in the example). Finally, select whether **supplemental cooling** in a tempering bath or with a cooling fixture is planned.

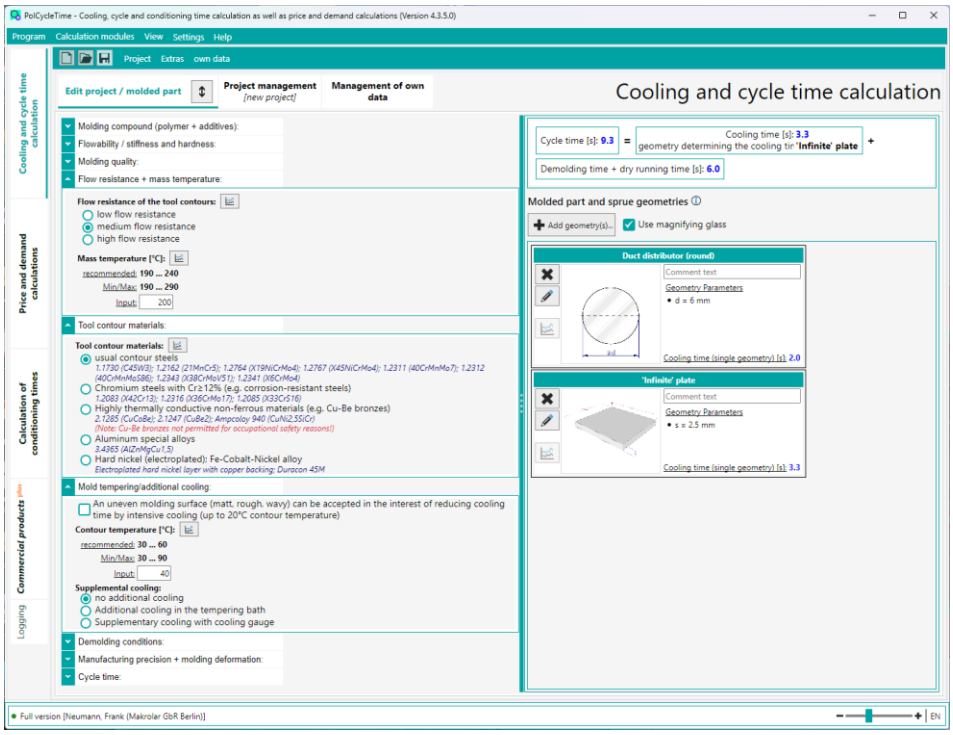


Figure 4: Flow resistance, tool contour materials and mould tempering

Melt temperature. The orientation ranges of the melt temperature represent the usual ranges in practice; they result from the thermal stability of the melt, the flow conditions during mould filling and the resulting part quality (surface gloss, weld line quality). Within these ranges, the melt temperature has relatively little influence on the cooling time. The temperature rise of the melt due to shear heating during injection is taken into account by an internal estimate of the injection pressure based on a minimum pressure specific to the moulding compound.

Flow resistance. The flow resistance of the part and sprue contours is assessed according to the user's experience; the decisive factor is the ratio of flow path to flow cross-section, while changes in the direction of the melt are almost irrelevant. The mould contours are filled by a laminar fountain flow. Raising the melt temperature and/or injection pressure is the most effective way to extend the possible flow path; a higher contour temperature, on the other hand, hardly reduces the flow resistance but considerably increases the cooling time. Larger flow cross-sections reduce the flow resistance disproportionately. As a guide for flat mould contours:

Wall thickness	Classification
below 1 mm	very thin-walled
1 to 2 mm	thin-walled
over 2 to 4 mm	normal wall thickness
over 4 mm	thick-walled

With wall thicknesses below 0.5 mm, reliable mould filling is not always guaranteed even with short flow paths.

Contour temperature. The mould wall temperature has a decisive influence on the cooling time: short cooling times require low contour temperatures, special part quality requires high ones. The choice is always a compromise that may only be decided by production trials. Without your own experience, estimate the possible deviations of the cooling time by varying the inputs (e.g. with the charts, section

3.6); further refinement is possible in discussion with part or moulding compound manufacturers. Also check whether the intended temperature control system can reach the contour temperature:

- water temperature control: up to 95 °C
- pressurized water temperature control: maximum 140 °C to 180 °C depending on the unit
- oil temperature control: maximum 200 °C to 350 °C depending on the unit

The type of coolant flow (constant or intermittent) has no significant influence on the cooling time. A frequently claimed strong reduction of the cooling time by pulsed cooling has not been proven, either theoretically or in practice, by verifiable investigations. **Supplemental cooling** in a tempering bath or with a cooling fixture parallel to the mould cycle shortens the production lead time, especially for thick-walled parts.

3.4 Demoulding, manufacturing precision and cycle time

- **Demoulding conditions:** sprue demoulding (no sprue waste, e.g. hot runner mould; sprues and parts demoulded spatially separated; without separation), expected deformation/damage during demoulding and quality degradation due to expected sink marks.
- **Manufacturing precision + moulding deformation:** normal, accurate or precision manufacturing and the expected part distortion (warpage).
- **Cycle time: Type of demoulding** (gravity, handling devices, manual operation), **Time for demoulding** (3 s in the example) and **dry running time** of the machine (2 s). You can adopt the dry running time from the data of an injection moulding machine via **"…"**.

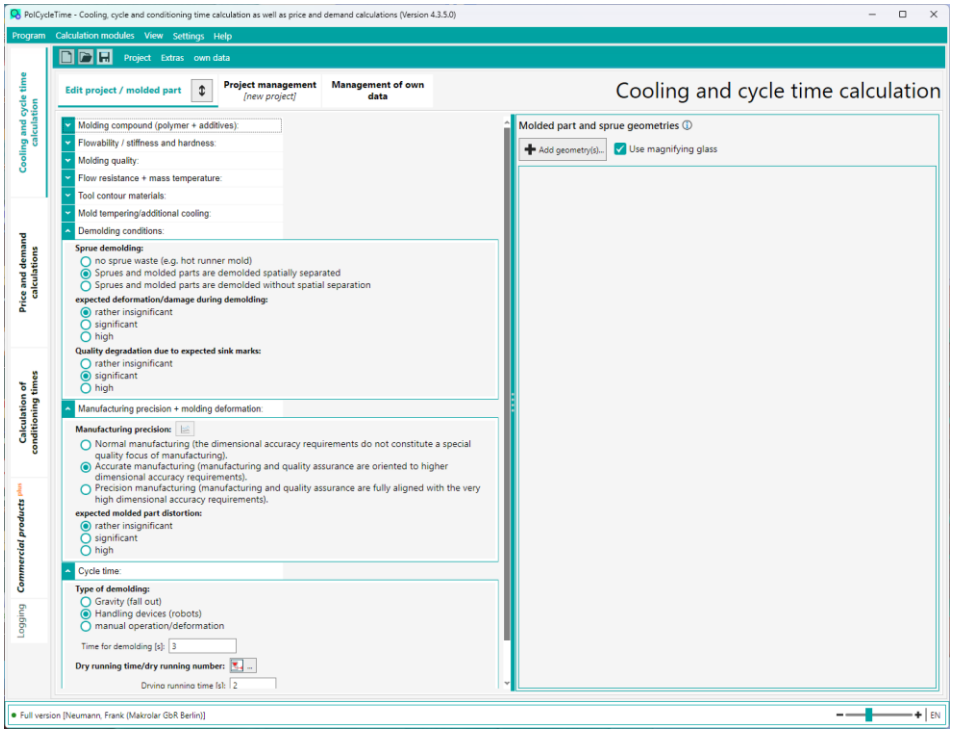


Figure 5: Demoulding conditions, manufacturing precision and cycle time

Demoulding conditions. If sprues are held in the mould by cooling, the type of demoulding determines the temperature equalization required (e.g. so that nothing sticks together due to remelting). Ejection systems (ejecting, stripping undercuts) can deform parts unacceptably through local pressure. With non-uniform temperature control, hot spots can cause demoulding problems.

Manufacturing precision. Production-related dimensional variations and distortion-related deviations of form, position and angle determine the dimensional accuracy immediately after production. Among other things, the decisive factor is the manufacturing and quality assurance effort the part manufacturer can provide; the tolerance series according to DIN ISO 20457 are intended for this. Special precision manufacturing is classified like precision manufacturing. The PolTolerances and PolTolerances-AC programs are suitable for determining the tolerance series.

Cycle time. The inputs for the cycle time are optional; without them, only the cooling time is shown.

- **Demoulding time:** for gravity demoulding (parts fall out), it is roughly assigned in three steps depending on the number of cavities (1; 1.5; 2 s). For handling devices and manual operation, enter it based on experience; with handling devices it is usually 2 to 6 s for small to medium-sized parts.
- **Dry running time:** according to EUROMAP 6 (dry cycle time), the time for mould and, if applicable, nozzle movements, a measure of the basic speed of the machine. It is taken from the machine documents or from the program file (standard level of the respective machine type, approx. 500 machines); reduced values due to power boosting must be entered directly. For the machine idle time in the cycle, the program applies a flat 1.5 times the dry running time. For multi-station machines, add the minimum station change time to the dry running time.

3.5 Moulded part and sprue geometries

Once all sections on the left have been completed, use **“Add geometry(s)…”** on the right to create the relevant wall thickness areas. In the window, double-click a basic shape on the **“Moulded part geometries”** or **“Sprue geometries”** tab, e.g. an “infinite” plate, cylinder, sphere, truncated cone or round runner. If **“Use magnifying glass”** is activated, the graphic under the mouse pointer is magnified.

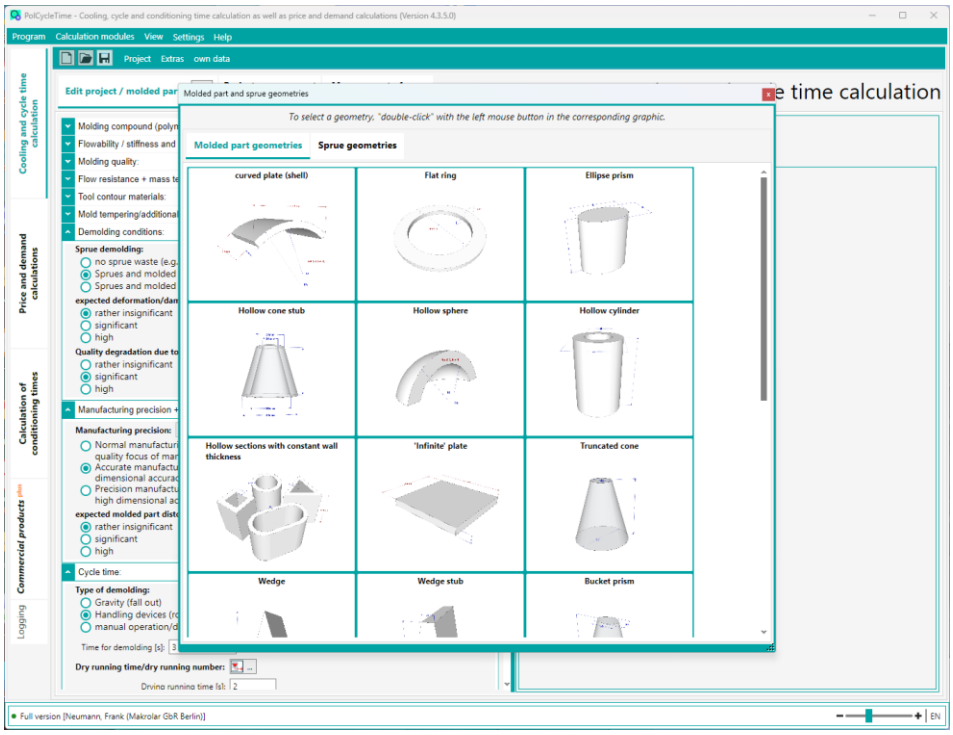


Figure 6: Selecting geometries

Each geometry appears as a card. As long as its dimensions are missing, the card has a red border. The pencil opens the schematic sketch where you enter the dimensions; the X removes the geometry.

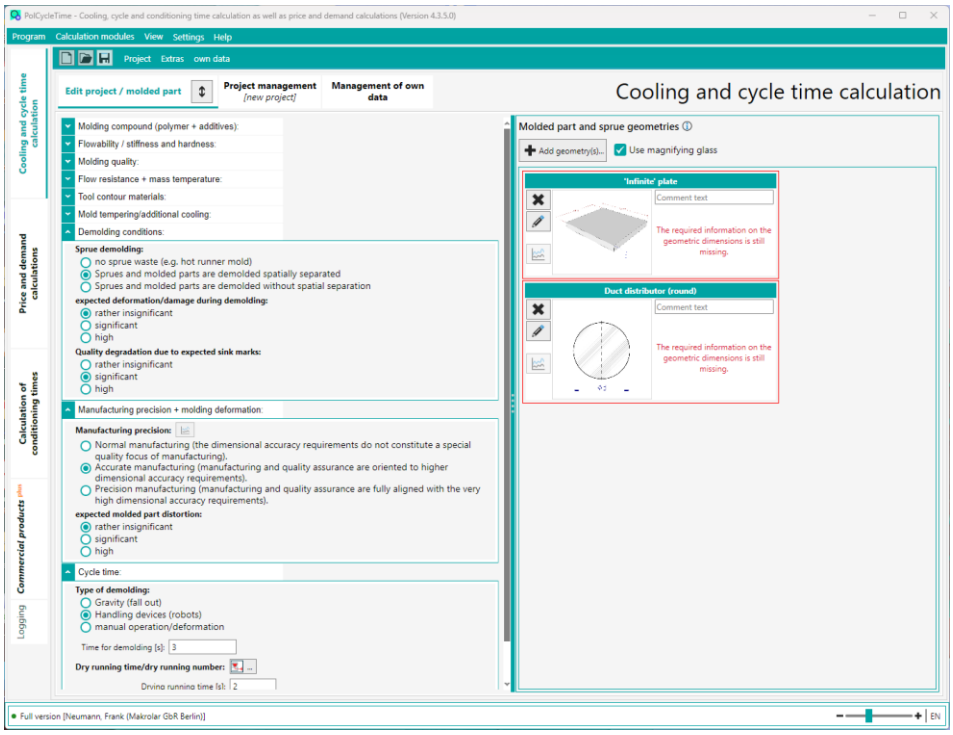


Figure 7: Newly created geometries without dimensions

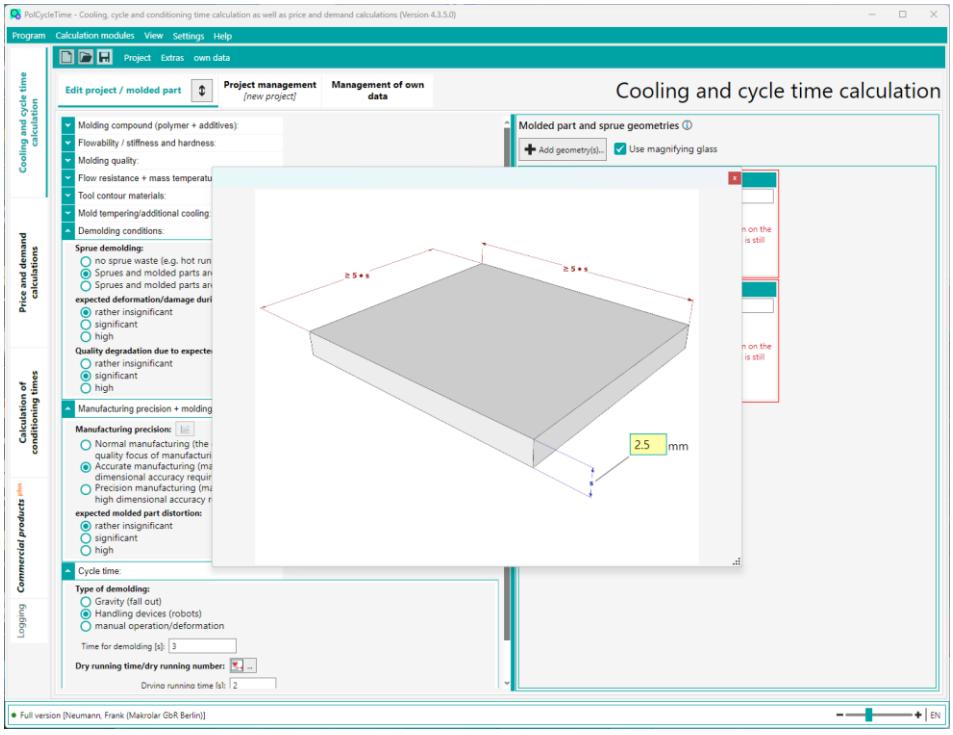


Figure 8: Entering the dimensions of a geometry (plate thickness 2.5 mm)

Assigning geometries. Injection moulded parts vary greatly in geometry. Mentally divide your part into sections that can be described with sufficient accuracy by the geometric elements offered, and check each section individually. The section with the longest cooling time determines the cycle.

- **Sprue geometry:** in injection moulding with a solidifying sprue, the runner cross-sections can determine the cooling time in unfavorable (usually avoidable) cases. For branched runner systems with the same cross-sectional shape, select the largest cross-section.

- **Moulded part geometry:** prismatic or profile-like sections can be straight or curved in the longitudinal direction. For cross-sections that vary in sections, the maximum values usually determine the cooling time.
- **Radius transitions** between part sections enlarge the cross-section; take this into account by increasing the wall thickness of the adjacent flat elements by approx. 25 % (input: s · 1.25).

3.6 Results and charts

As soon as all inputs and dimensions are available, the results are shown at the top right:

- **Cooling time** and the **geometry determining the cooling time**: the geometry with the longest cooling time. In the example this is the plate with 3.3 s; the round runner needs 2.0 s. Each card shows the **cooling time (single geometry)**.
- **Demoulding time + dry running time** (6.0 s in the example).
- **Cycle time** = cooling time + demoulding time + dry running time (9.3 s in the example).

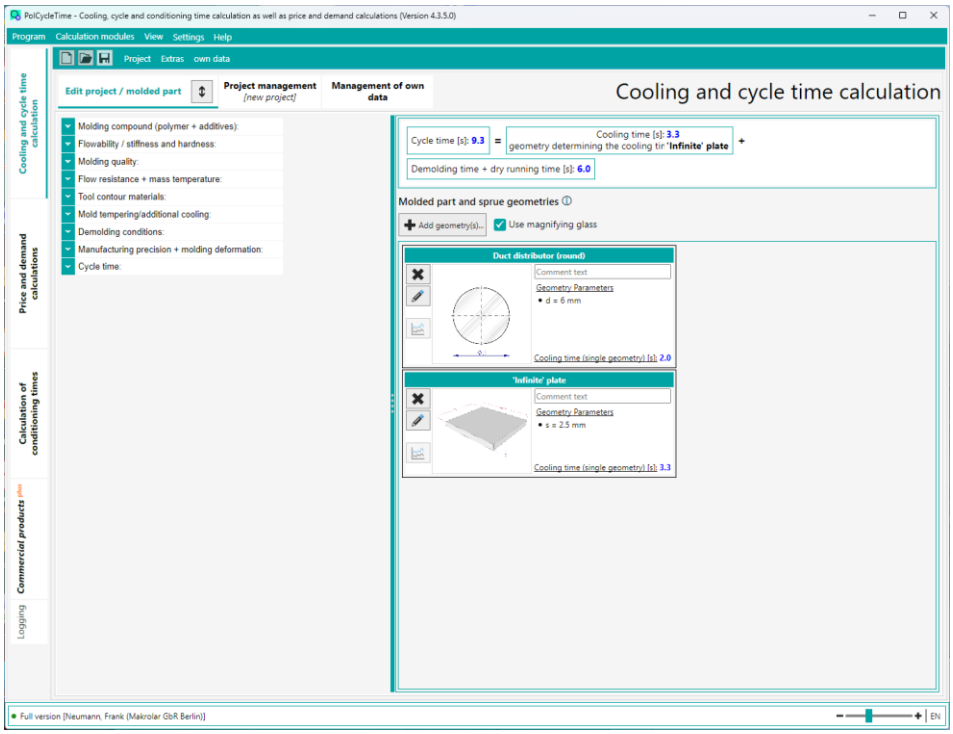


Figure 9: Results of the cooling and cycle time calculation

The small chart buttons next to mass temperature, contour temperature, flowability etc. and on the geometry cards open the chart window with the **cooling time dependencies**. It shows how the selected quantity affects the cooling time of a geometry; the current value is highlighted. The window can remain open while you click further chart buttons. The charts are only available once all inputs are complete and results are displayed. Dependency charts are available for flowability, flow resistance of the tool contours, melt temperature, tool contour materials, contour temperature and manufacturing precision; depending on the quantity, the cooling times are shown as a line or bar chart. For example, you can read off how much the cooling time would increase if precision manufacturing were required.

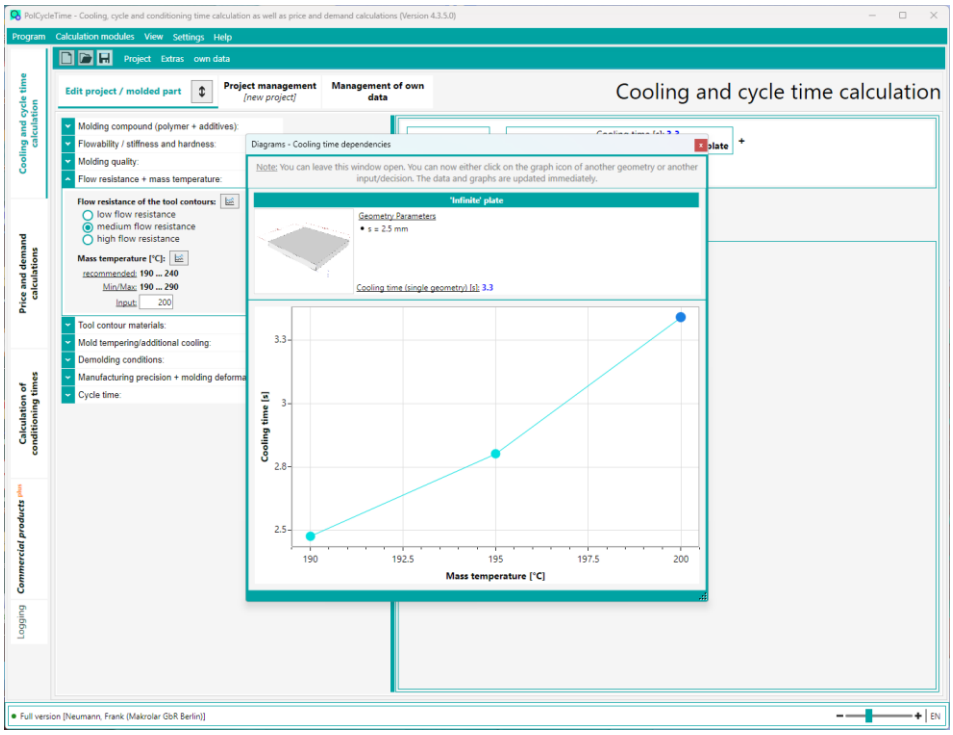


Figure 10: Cooling time of the plate as a function of the melt temperature

3.7 Subsequent changes

All inputs can be changed at any time; the results are recalculated immediately. However, some decisions depend on each other: if, for example, you subsequently select a **different polymer**, the dependent inputs are reset (among others moulding quality and mass temperature). The affected section headings turn red again, the results disappear, and you have to enter this data again.

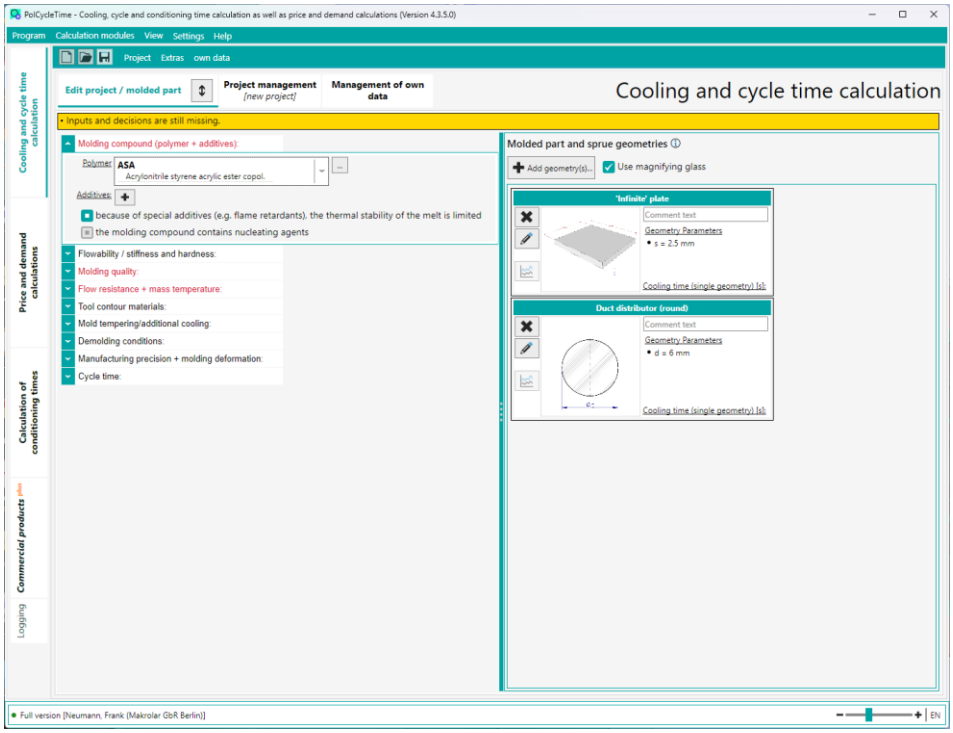


Figure 11: After changing from ABS to ASA, dependent sections are red again

3.8 Residence time calculation

Use **“Extras” → “Residence time calculation”** to check how long the melt remains in the plasticizing cylinder. The data of the current project is adopted; add the **Stroke volume**, **Number of cavities**, **Part weight** and the **sprue material surcharge**. You can calculate the melt density via **“…”** (chapter 6).

Below, a table compares the permissible residence times of common plastics, taking thermal degradation at the selected melt temperature into account. In the example (stroke volume 600 cm³, 2 cavities, part weight 18 g), the residence time is 3.29 minutes.

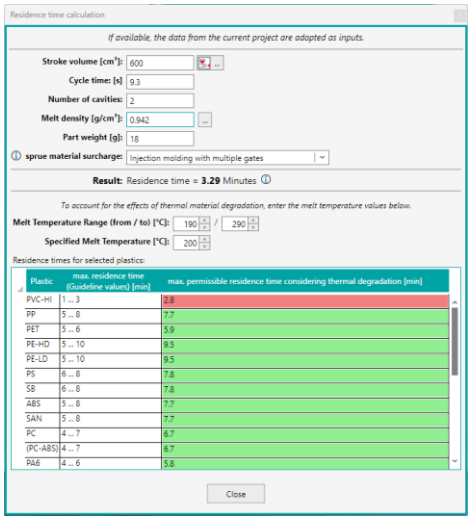


Figure 12: Residence time calculation

The calculation assumes three-zone screws. The output volume per shot is taken as 1.5 times the calculated stroke volume of the screw; this stroke volume can be found in the machine data of the injection unit used (ISO). The number of cavities and the part weight are needed for the shot weight; for family moulds, the associated group of parts is treated as one part. Material losses and sprue portions are roughly taken into account. According to the ISO recommendation, the limit for unacceptable thermal degradation of the material is approx. 6 min; machine manufacturers and moulding compound suppliers provide more precise guide values. Examples:

Plastic	Permissible residence time [min]
PP	5 … 8
PE-HD, PE-LD	5 … 10
PS, SB	6 … 8
ABS, SAN	5 … 8
PC, (PC+ABS)	4 … 7
PA6, PA66, PA11, PA12	4 … 6
POM	3 … 5
PMMA	4 … 6
PVC, PVC-HI, PVC-P	1 … 3
PPS	5 … 10
PEEK	5 … 10
PBT, PET	5 … 6
TPE, TPU	4 … 8

3.9 Own data

The **“Management of own data”** tab and the **“own data”** menu manage **own polymers**, **own additives** and **own IM machines** (injection moulding machines). Use **“+ Add…”** to create an entry, the pencil to edit it, the eye to display the data and the X to delete it (after confirmation).

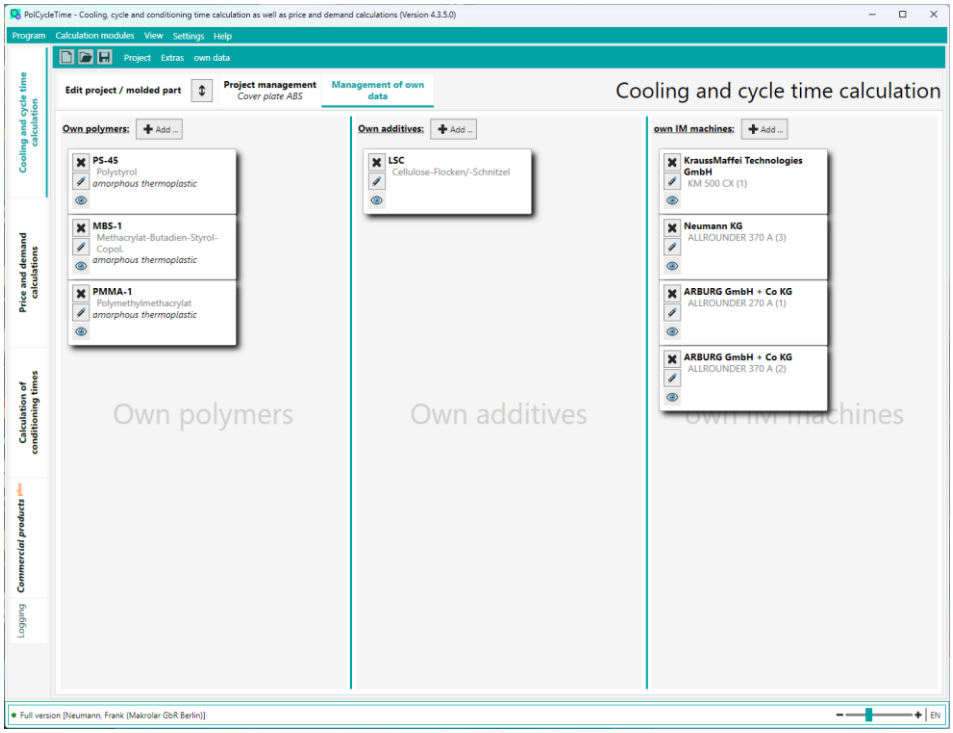


Figure 13: Own polymers, additives and injection moulding machines

For an own polymer you enter, among other things, the name, polymer structure (amorphous or semi-crystalline), glass transition temperature, density, modulus of elasticity, mould contour temperature and melt temperature (each from/to), specific volume, heat capacity, thermal conductivity and minimum injection pressure. Use the button for adopting data from the database as a template to start from an existing material.

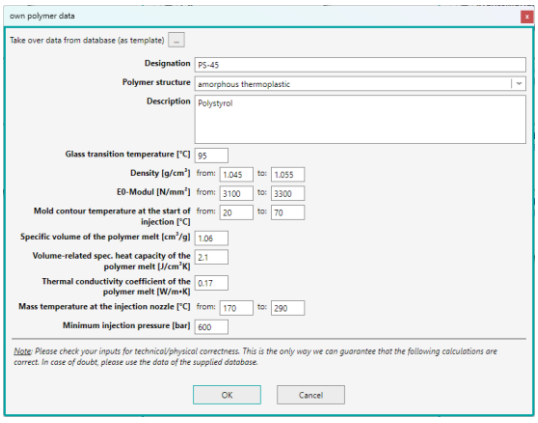


Figure 14: Editing an own polymer

For an own injection moulding machine you enter the name, manufacturer, dry running time, maximum clamping force, injection unit and stroke volume. You can then adopt the dry running time in the **“Cycle time”** section via **“…”**.

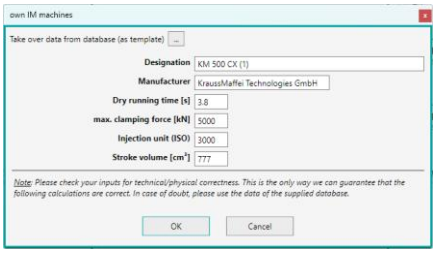


Figure 15: Editing an own injection moulding machine

An own polymer or additive that is used in the current project cannot be deleted; if you change data relevant to the cooling time, the results are updated immediately. The name must be unique.

> **Important:** Check your inputs for technical and physical correctness. Only then are the calculations correct; if in doubt, use the data of the supplied database.

3.10 Saving and printing

The **“Project”** menu contains commands to create a new project, load, save and save a project under a new name, as well as **print / print preview**. Cycle time projects are saved with the extension **.polcyc**, by default in the folder **Documents\PolCycleTime Files**. The report contains the project header, results, all inputs and sketches of the geometries.

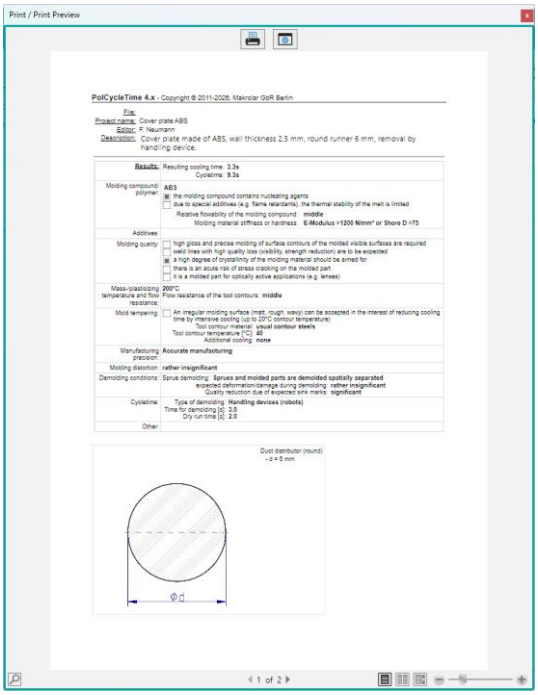


Figure 16: Print preview of the cooling and cycle time calculation

3.11 Technical background

Cooling time minimum at certain melt temperatures. As the melt temperature rises, more heat has to be dissipated, so the cooling time should increase continuously. However, the program also takes into account the shear heat that prolongs the cooling time; it is generated mainly in the outer layers during volumetric filling and is dissipated faster at higher melt temperatures. These opposing influences can lead to a usually very flat cooling time minimum in the chart within the usual melt temperature range. It is the higher, the greater the contour temperature, injection pressure and surface-to-volume ratio of the contour determining the cooling time.

Accuracy of the moulding compound data. The molten state is decisive for the cooling time calculation. Exact mixing rules apply to specific volume, specific heat capacity and heat of fusion; for the thermal conductivity, a model correlated with measurement results is used (not the Maxwell model). It is sufficiently accurate up to approx. 60 vol.-% additive content; with crystalline additives with strongly direction-dependent properties, noticeable errors are possible. Overall, deviations of the cooling time of no more than ± 10 % are expected.

Demoulding temperature. It has a great influence on the cooling time and, depending on the requirement, describes a mean temperature level of the moulded part or its maximum temperature in the middle of the cross-section. The reference temperatures specific to the moulding compound (glass transition, melting, flow temperature) are covered in three moulding compound groups. For the moulded part, the demoulding temperature is differentiated in five levels – depending on supplemental cooling, manufacturing precision, cross-section thickness, stiffness or hardness, demoulding conditions and sink marks. For sprues there is a three-level assignment according to the demoulding conditions, for semi-crystalline polymers additionally according to the cross-section thickness. That is why the program does not ask for a fixed value but derives it from your decisions.

3.12 Typical injection moulding defects

The following overview helps to assign typical defects to their most common causes:

Defect	Appearance	Typical cause
Sink marks	depressions on the part surface	non-uniform shrinkage
Burn streaks	brownish discoloration of the surface	melt temperature too high or residence time too long
Air streaks	matt, brownish, silver or white streaks at wall thickness transitions and gates	air in the mould is overrun and trapped by the melt
Moisture streaks (splay)	large, matt, streaky areas	water in the mould or in the granules
Color streaks	uneven coloring	insufficient mixing, incompatible masterbatch
Glass fiber streaks	matt, rough surface	flow orientation, cooling too fast
Air inclusions (bubbles)	voids on/in the part, bulges near the wall	air not escaped, back pressure too low, decompression too strong/fast
Voids (vacuoles)	air-free voids in the part	insufficient compensation of shrinkage
Gas inclusions	bubbles in or on the surface	material decomposition, residence time too long or shear too high
Weld lines	optical/mechanical weak point (notch, discoloration)	flow fronts meet with too little pressure/temperature
Gloss differences	gloss too high, too low or uneven	different cooling or shrinkage conditions
Jetting	snake-like, rough/matt line starting at the gate	no fountain flow, pressure too high, sudden widening of the cross-section
Record grooves	finely ribbed, concentric surface	melt temperature, injection speed or mould temperature too low
Matt areas at the gate	matt halo around the gate	gate too small, injection speed too high

Defect	Appearance	Typical cause
Short shot	contour not completely formed (usually far from the gate)	premature freezing, injection pressure/speed too low, venting problems
Diesel effect / burns	burns and unfilled areas	insufficient venting
Flash	film-like edge beyond the nominal contour	inaccurate mould, melt viscosity too low, clamping force too low, cavity pressure too high
Stress whitening / stress cracks	whitish discoloration, oriented cracks	a limit deformation or load has been exceeded
Ejector marks	bulges, gloss differences, markings	process-related, geometric, thermal or mechanical causes
Deformation during demoulding	cracks, fractures, overstretching (typical for undercuts)	the part cannot absorb the demoulding forces
Drag marks	damaged, usually textured surface	mould stiffness too low, shrinkage too high, draft angle too small
Delamination of the surface	material layers peel off	incompatible additives, contamination, moisture, injection speed too high
Cold slug	comet-tail-like mark near the gate	cooled melt from the nozzle or hot runner enters the cavity
Stringing	strings at the sprue	insufficient cooling in the gate/sprue area
Black specks	dark spots on the surface	mould wear, thermal degradation or contamination of the melt
Mould deposit	disturbances of gloss and topography	mostly low-molecular deposits on the mould surface
Defects after electroplating	blisters, pimples, insufficient adhesion	if they occur periodically, usually the injection moulding process or handling
Defective film hinge	stress whitening, torn or cracked hinge	overstressing, e.g. during demoulding, frozen moulding compound
Warpage	deviation from the nominal shape	differences in shrinkage or deformation during demoulding

4 Price and demand calculations

The module calculates unit costs, mould demand, mould loading (number of cavities), machine utilization, machine hourly rate and lot sizes. A calculation project can contain several **variants** side by side, e.g. different numbers of cavities. Example: the cover plate from chapter 3 is to be produced 1.2 million times in five years; a 2-cavity and a 4-cavity mould are compared.

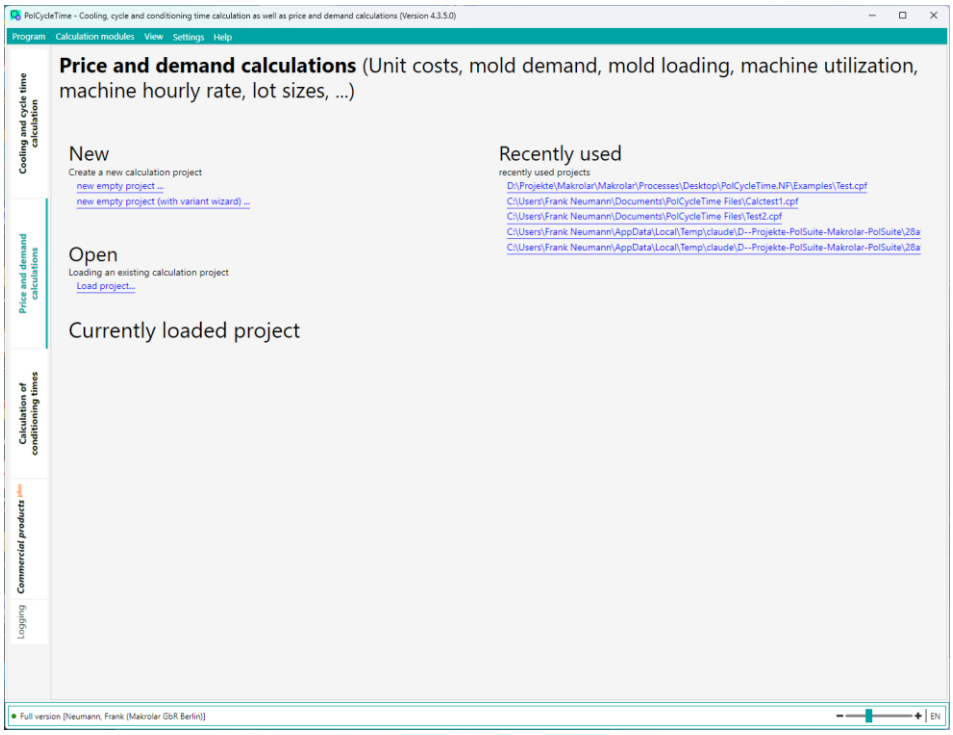


Figure 17: Start page of the price and demand calculations

The main functions of the module are the calculation of the unit costs and the mould demand, the determination of the optimum mould loading (number of cavities), the determination of the machine utilization, the calculation of machine hourly rates and the determination of economic (profit-optimized) lot sizes – for injection moulded and compression moulded plastic parts.

Each project is saved in its own file and can contain up to **10 variants**. You can create an **empty project** without inputs or use the **variant wizard**, which guides you through the inputs of the first variant. You open an existing project via **"Load project..."** or by clicking it in the **"Recently used"** list, which shows the last five projects.

4.1 New project with the variant wizard

Click **"new empty project (with variant wizard)..."** and first specify the file name (extension **.cpf**). The wizard guides you through the following steps:

1. **Variant name and background color:** the color helps to distinguish the variants in the overall view.
2. **Manufacturing process and dimensional accuracy:** e.g. injection moulding of thermoplastics and accurate manufacturing.
3. **Quantities and rejects:** annual quantities for up to five years and estimated rejects. If you select the calculation of the optimum lot size, you also enter the set-up time, cost-based rate of return and imputed interest rate.
4. **Machine running time and cycle time:** shift system (1, 2 or 3 shifts), available machine running time, downtimes and the **cycle time** (e.g. from chapter 3; 9.3 s in the example).
5. **Mould, number of cavities and mould costs:** mould type, technically possible maximum and required minimum number of cavities with estimated acquisition costs, mould contour costs, selected number of cavities and mould costs used for the calculation.
6. **Wear:** complexity of the mould (slider), mechanical stress, hardness of the contours, abrasion by fillers and surface finish. These result in the wear-related tool life (number of shots) and the quantity used for mould depreciation.

7. Click **“Finish”**.

You can also leave inputs open in the wizard and add them later. However, the order of the pages is chosen so that **orientation values** are calculated from the previous data at the appropriate points and offered for adoption; if data is missing, no orientation value may be shown.

> **Tip:** Orientation values appear next to the input field (~ … ⓘ). The tooltip of the ⓘ symbol names the inputs on which the value depends. Clicking the **“←”** button in front of it adopts it as an input. Orientation values are rounded to whole numbers; under **“Settings” → “Options…”** you specify the power of ten to which they are rounded.

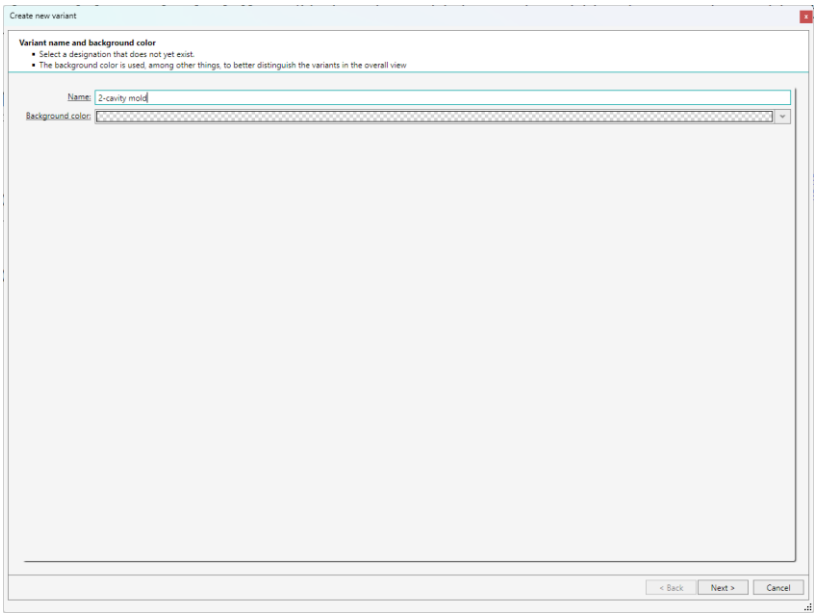


Figure 18: Wizard: variant name and background color

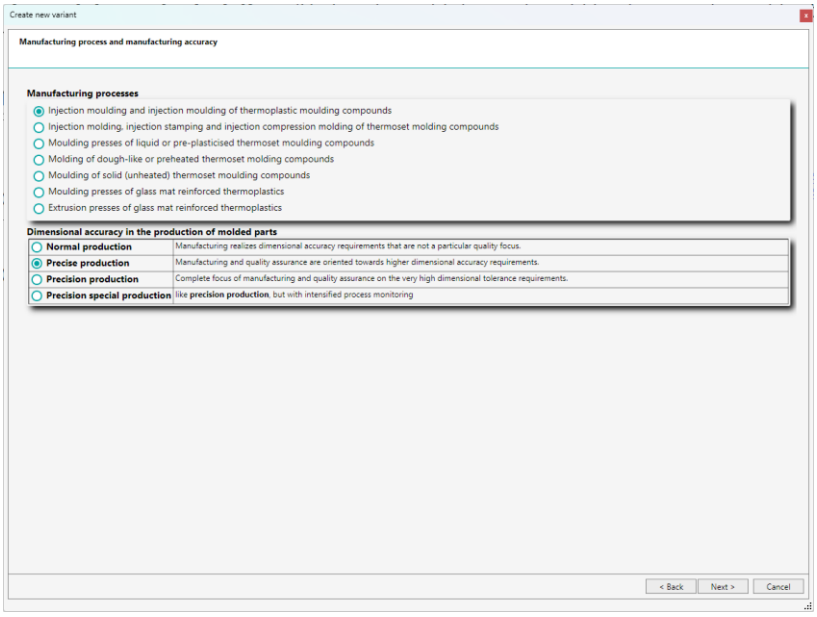


Figure 19: Wizard: manufacturing process and dimensional accuracy

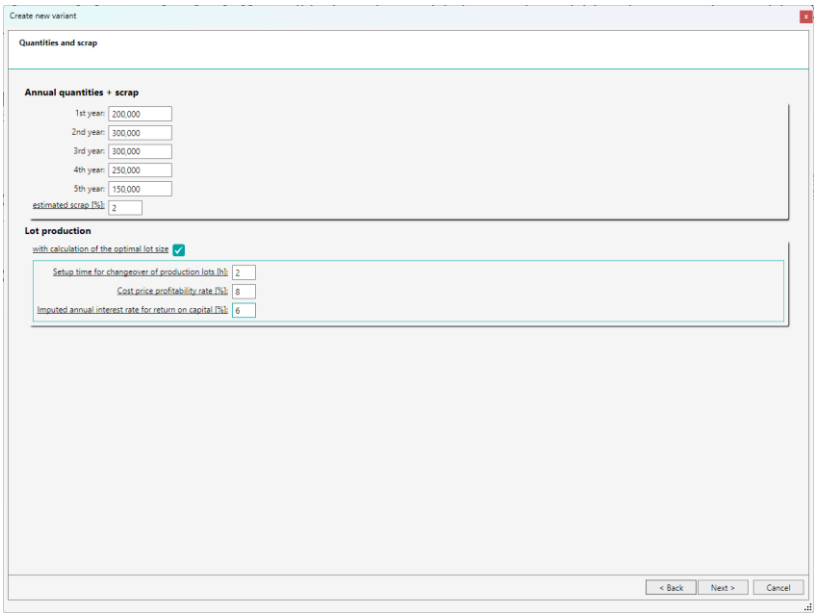


Figure 20: Wizard: quantities, rejects and lot production

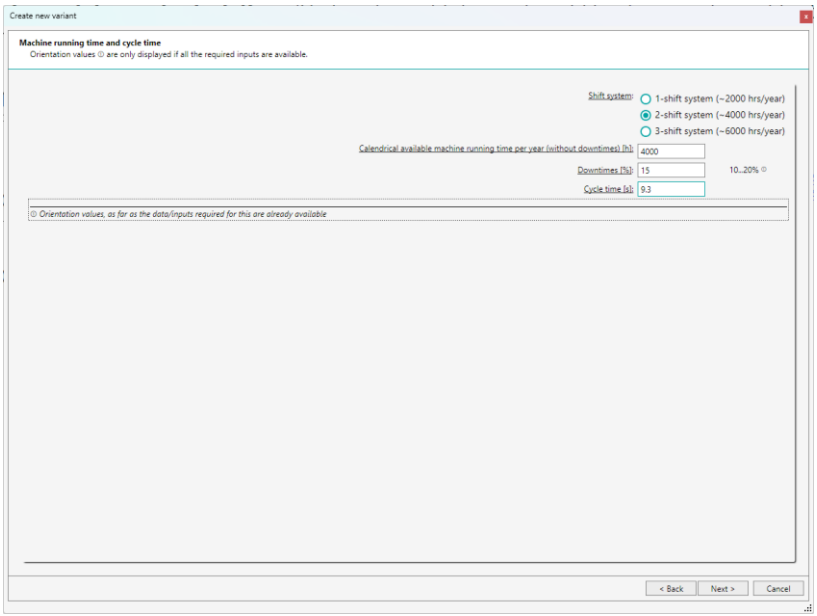


Figure 21: Wizard: machine running time and cycle time

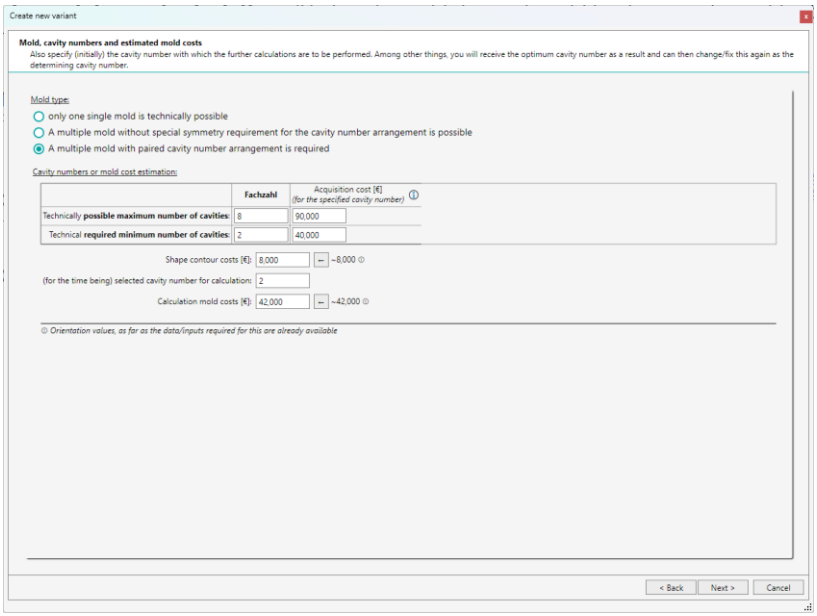


Figure 22: Wizard: mould, number of cavities and mould costs

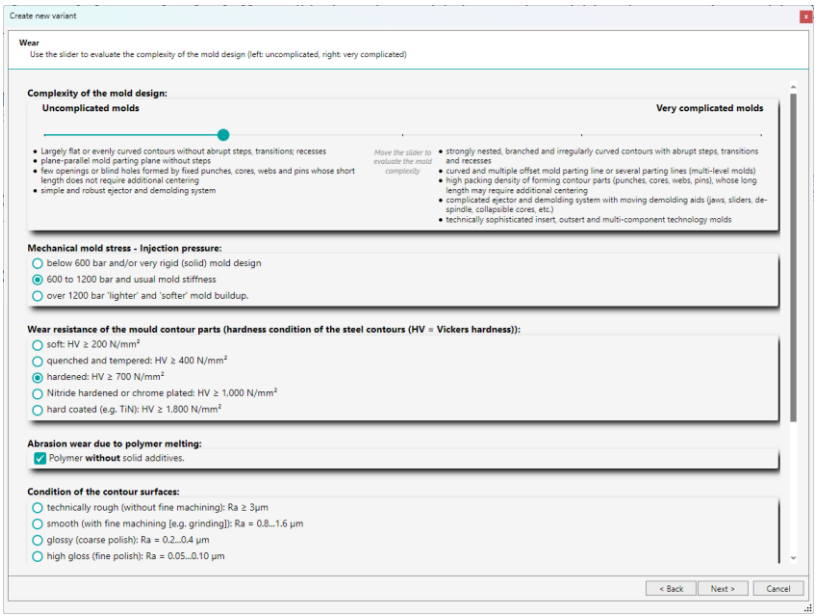


Figure 23: Wizard: wear (mould design and stress)

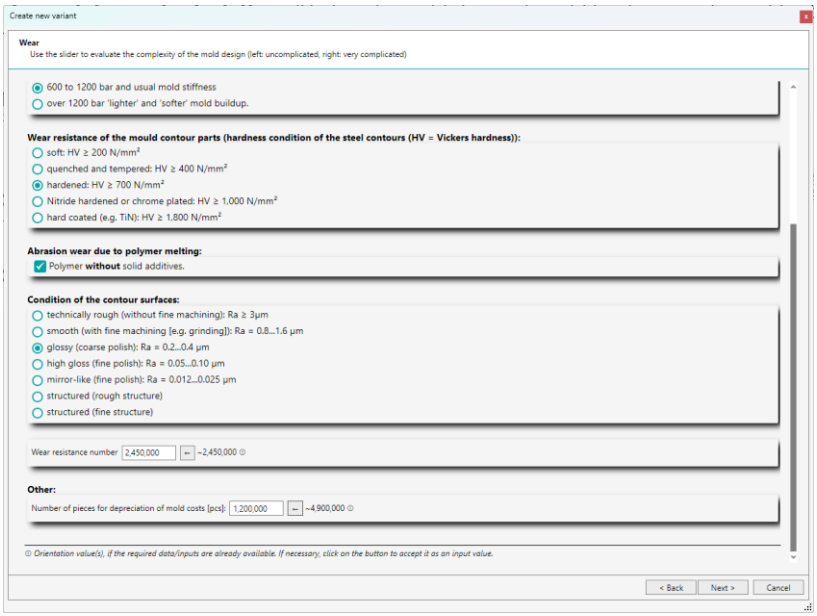


Figure 24: Wizard: contour surface, tool life and depreciation

4.2 Material, production and QA costs

The wizard does not record material, production and QA costs. After finishing, click the pencil of the corresponding section in the variant:

- **Material costs:** moulded part mass, material allocation price, sprue waste (single or multiple gate) and material loss supplement. In the example: 18 g per part, 2.60 €/kg, multiple gate.
- **Production costs:** single-machine or multi-machine operation, number of machines operated by one person, selection of the **machine hour rate** (hourly rate 1 … 3 with different cost portions, or your own calculation) and working time cost rate. In the example: hourly rate 2 with 45 €/h, working time cost rate 38 €/h.
- **QA costs:** quality assurance supplement (5 % in the example).

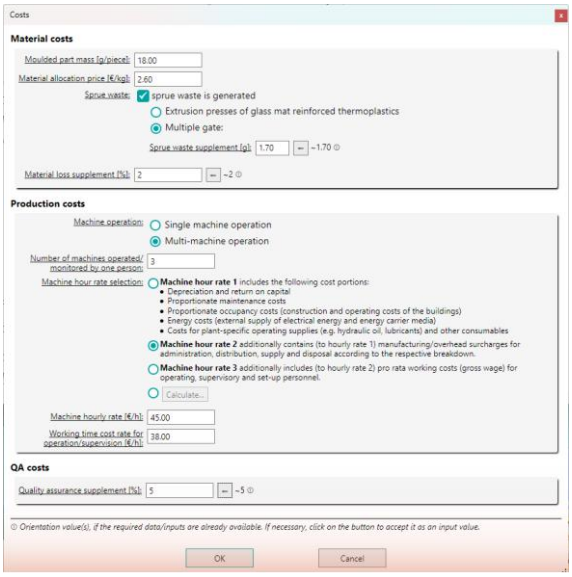


Figure 25: Material, production and QA costs

4.3 Results and comparison of variants

Each variant is shown in its own column. In the upper area **“Results, orientation values and unit cost distribution”** you find:

- **Results overview:** available annual machine running time, number of cavities (optimal, due to wear, due to production, economic, used for calculation), machine occupancy times per year, wear piece count, total mould demand, machine hourly rate, material, production, QA and mould costs per piece, **total unit cost** and economic lot size.
- **Unit cost distribution:** pie chart of the cost portions.
- **Inputs vs. orientation values:** comparison of your inputs with the orientation values.

You add another variant via **“Variants”**, via the wizard or with the copy icon in the bar of a variant. In the example, a part costs 0.182 € with the 2-cavity mould and 0.159 € with the 4-cavity mould.

A **new empty variant** contains no inputs, a variant **created with the wizard** is entered step by step, and a **copy** immediately adopts all inputs of the copied variant. For a copy, edit the name and background color right away so that the variants can be distinguished. A variant is deleted after a confirmation prompt; if the project no longer contains any variant, you can create a new one directly in the empty window.

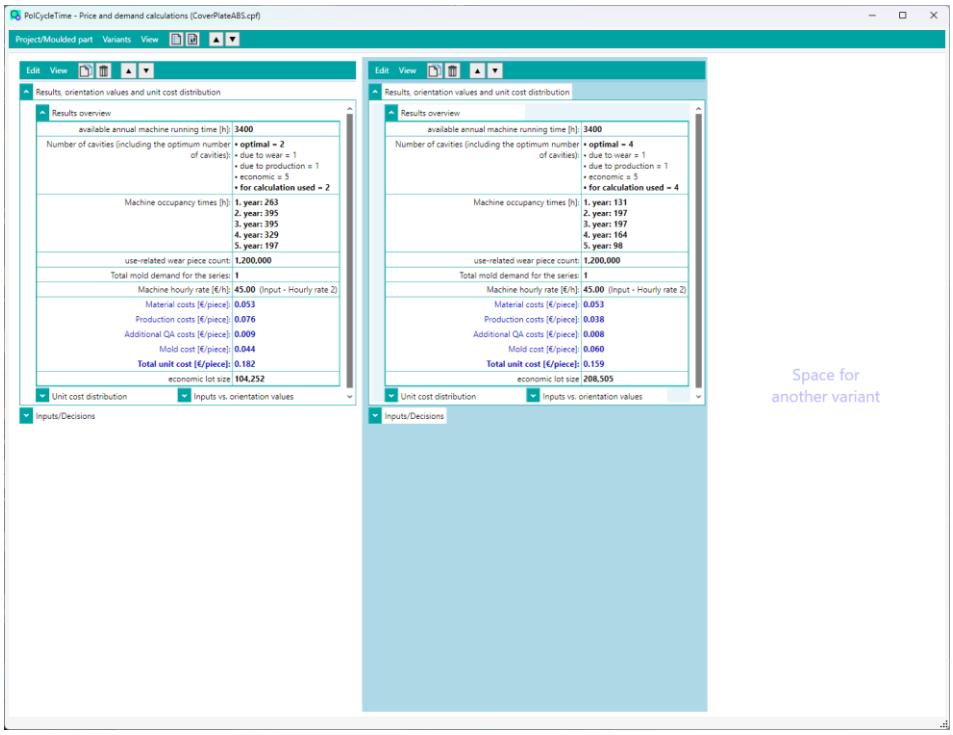


Figure 26: Results overview of two variants

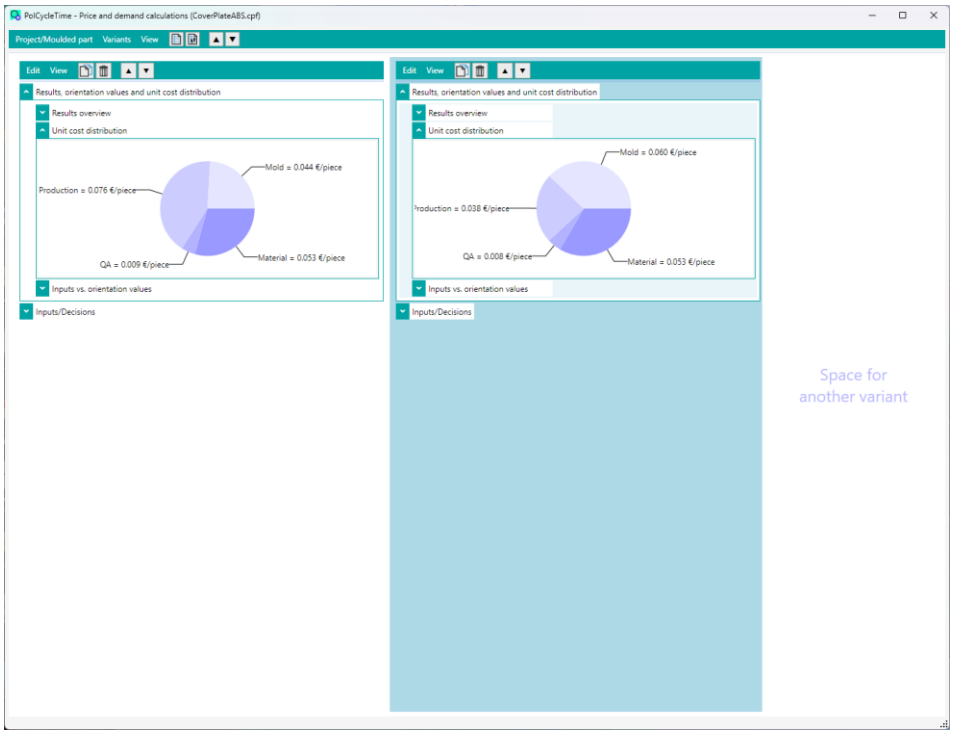


Figure 27: Unit cost distribution of both variants

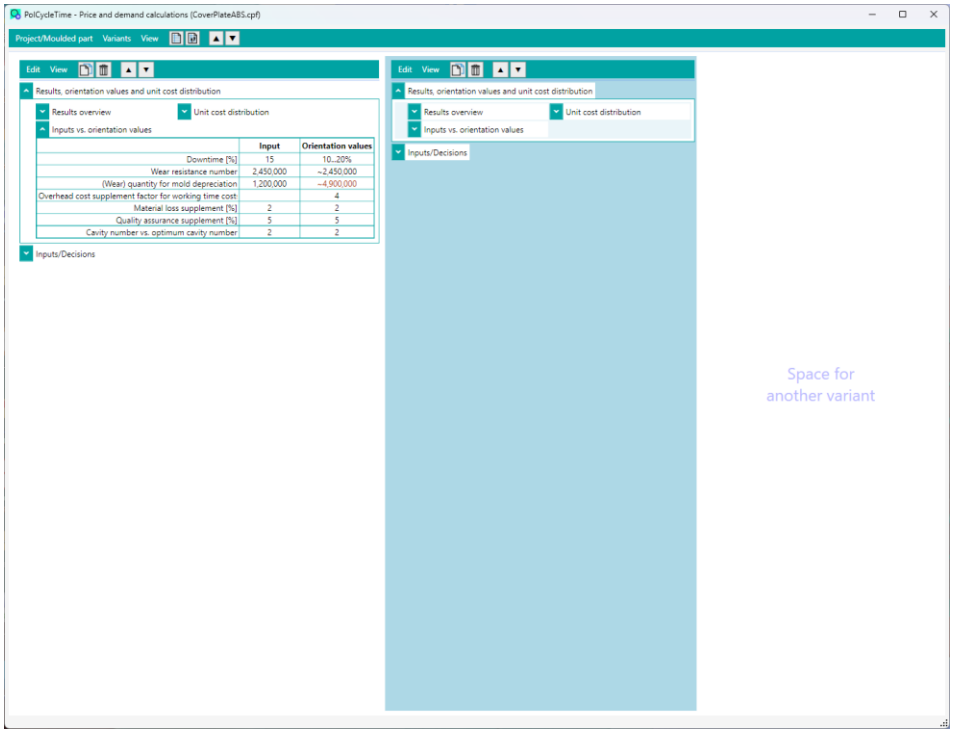


Figure 28: Inputs compared with the orientation values

In the **“Inputs vs. orientation values”** view, orientation values are marked red if they differ from your input. This shows at a glance where your assumptions differ from the calculated expected values.

The lower area **“Inputs/Decisions”** summarizes all inputs of the variant; each section can be edited with the pencil or via the **“Edit”** menu of the variant. A red section heading indicates missing or incorrect inputs; if the higher-level heading **“Inputs/Decisions”** is also red, something is still missing in one of the sections. Use the arrows in the bar to move variants and the wastebasket to delete a variant.

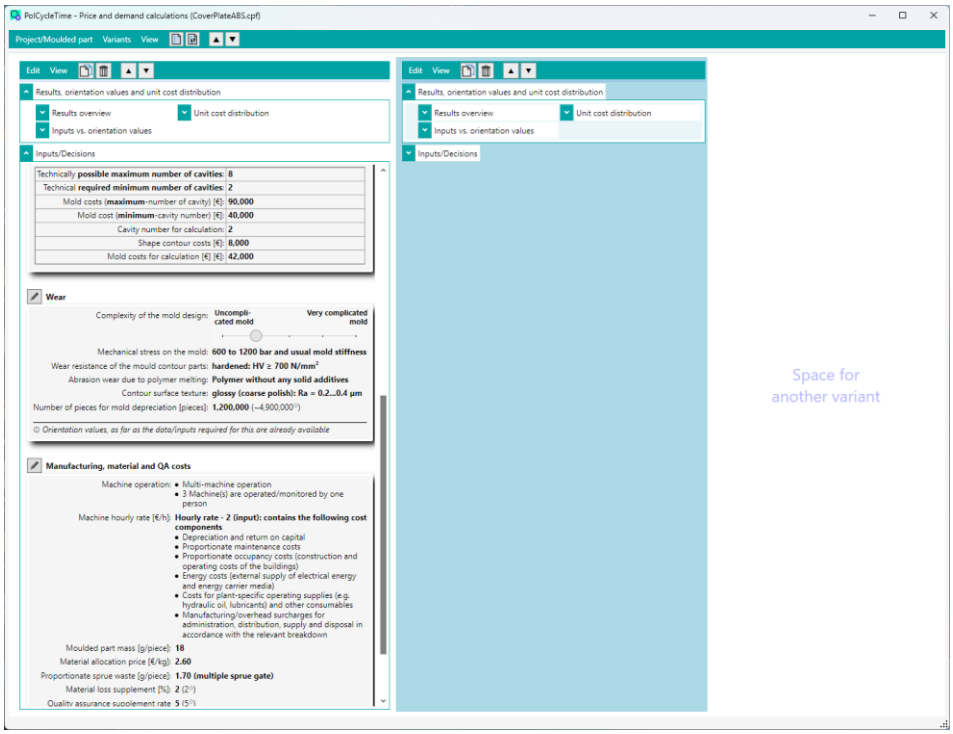


Figure 29: Inputs/decisions of a variant

4.4 Basic data and printing

Via the **“Project/Moulded part”** menu you edit the basic data – project/part name, processor and description – and open the print preview. In the print preview, select the **variant** to be printed at the top.

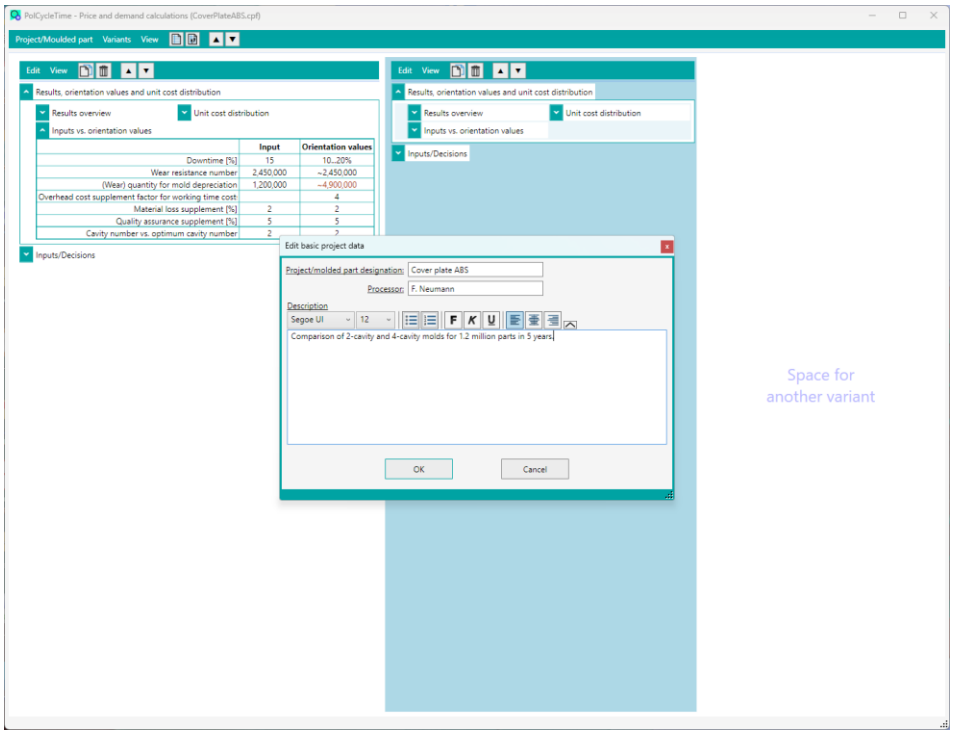


Figure 30: Editing the project basic data

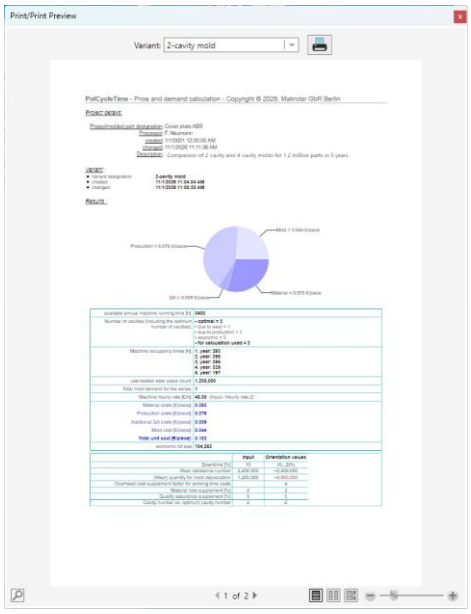


Figure 31: Print preview of a variant

> **Note:** The **“View”** menu of the calculation window expands or collapses the groups of all variants together.

5 Calculation of conditioning times

Polyamide parts are almost dry after injection moulding and therefore brittle. During conditioning (storage in a humid, warm environment), they absorb water until they reach the moisture content required for use. The module calculates the time required for this. Example: a **plain bearing bushing made of impact-modified PA66** with a wall thickness of 3 mm for outdoor use.

5.1 Background and calculation concept

As the water content increases, application-relevant properties of the plastics change:

- increase in dielectric losses
- decrease in stiffness and hardness
- increase in toughness (impact strength, elongation at break)
- increased dimensional change due to swelling or drying out

The maximum water absorption up to saturation varies greatly: for non-polar plastics (e.g. polyolefins) it is often negligible, for polar plastics such as polyamides it must be taken into account. The desired water concentration is then introduced by conditioning. Diffusion processes in compact solids are much slower than heat conduction, and the conditioning time increases with the square of the wall thickness. That is why conditioning usually takes place in temperature-controlled hot water baths (40 °C to 90 °C) or in saturated steam autoclaves (above 100 °C).

The conditioning temperature must be matched to the thermal stability of the plastic. Depending on the additives and the production-related structure (e.g. degree of crystallinity), short, aggressive conditioning processes can cause discoloration, deposits, warpage or cracks; conditioning in a warm, humid climate in climatic chambers is gentler.

Calculation concept. Transient water vapor diffusion is described with the same mathematical formalism as transient heat conduction: concentration fields are calculated like temperature fields, with the

thermal diffusivity replaced by the diffusion coefficient. A saturated water vapor layer is always assumed at the part surface, so the mass transfer resistance is negligible. Purely diffusion-controlled mass transport is assumed; capillary processes due to porosity are not taken into account. Plastics with large proportions of solid additives (e.g. above 50 vol.-%) may not meet this condition because of poor bonding between matrix and additive. The calculation is based on the solution by Jouwersma (Die Diffusion von Wasser in Kunststoffe, Chemie-Ing.-Techn. 31 (1959) 10, pp. 652–658).

5.2 Inputs

- **Plastic:** a polyamide from the list or via the material selection window **"…"**, including own materials (section 5.4; they are shown in italics in the selection). The program shows the water saturation concentration (PA66-HI: 7.9 %).
- **Plastic designation:** free text for the printout.
- **Conditioning or application condition:** for **Indoor climate**, select the environment from a list, e.g. fully air-conditioned, heated and ventilated, frost-free humid room or weather-protected outdoor area. For **Outdoor climate**, **"Select/change climate zone…"** opens a world map of the climate zones (continental climate and maritime climate tabs).
- **required/medium moisture content:** the orientation value for the selected condition can be adopted with **"←"** (0.7 % in the example).
- **Conditioning temperature** (70 °C in the example) and **Starting moisture content** (0 % for conditioning immediately after production).
- **Partial geometry(s):** via **"Add…"**, as for the cooling time calculation (section 3.5); in the example a plate with s = 3 mm.

On the map, move the mouse pointer onto the colored area of the desired climate zone (the magnifier enlarges the area under the pointer) and select it by **double-clicking**. The program then shows the selected climate zone and the absolute humidity at the base point. In the example: "winter extreme cold climate" with 1.8 g/m³.

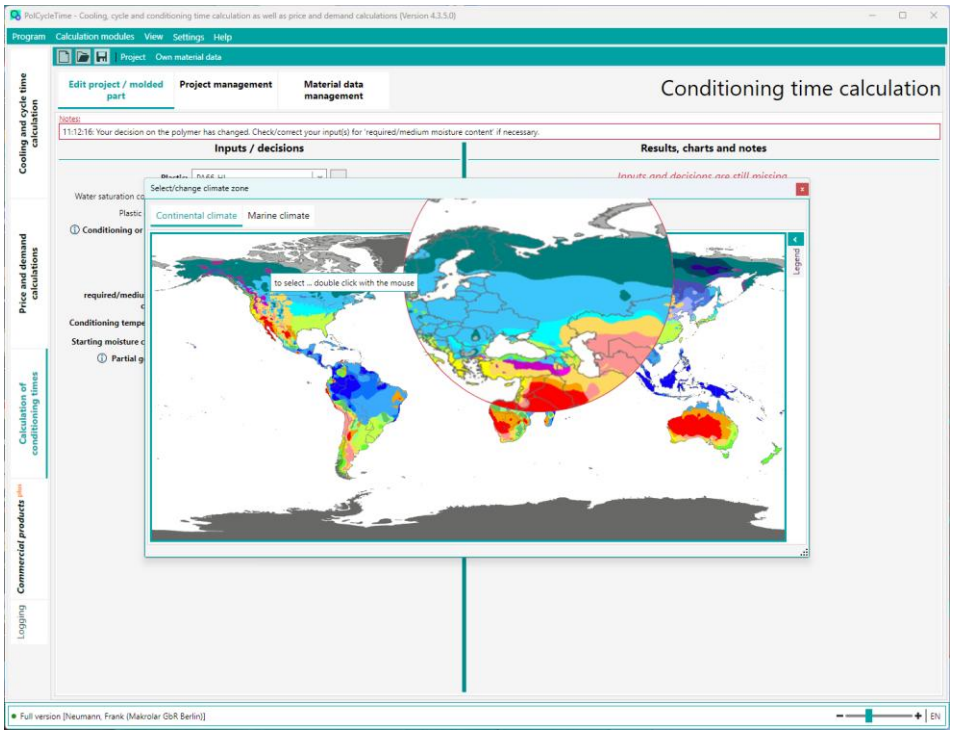


Figure 32: Selecting the climate zone on the world map

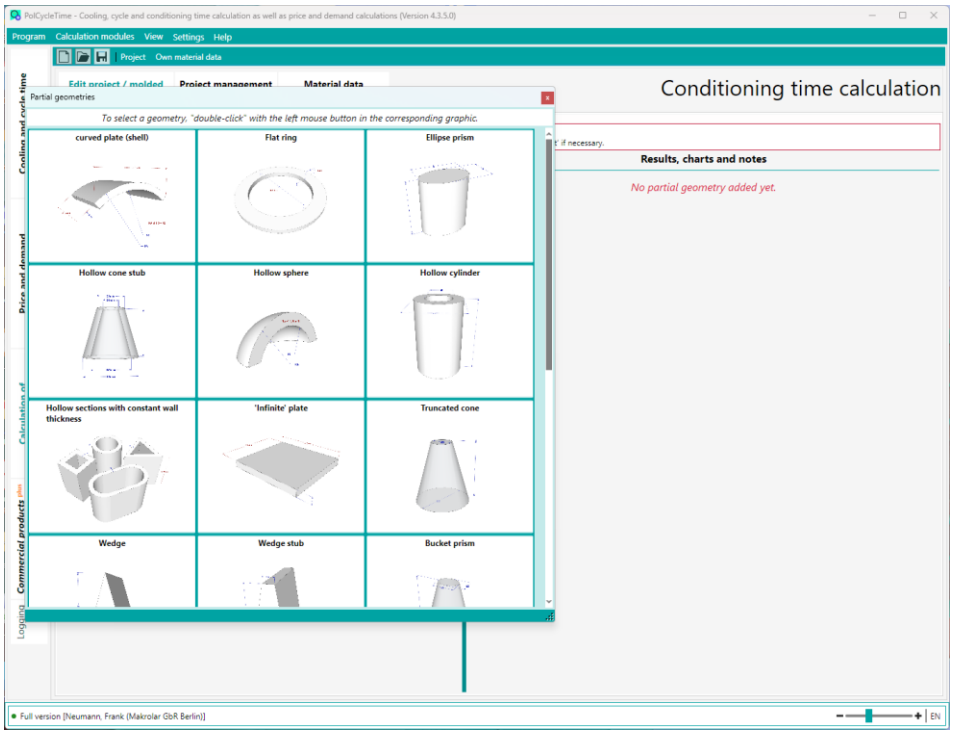


Figure 33: Partial geometries for conditioning

5.3 Results and chart

On the right, the **conditioning time**, the **conditioning time-determining geometry** and the times of the individual geometries are shown. In the example, conditioning at 70 °C takes **0.63 hours**.

The chart shows the conditioning time as a function of the **conditioning temperature** or the **starting moisture content**; you set the range of the X-axis with the slider. For example, you can see that a higher temperature greatly reduces the conditioning time.

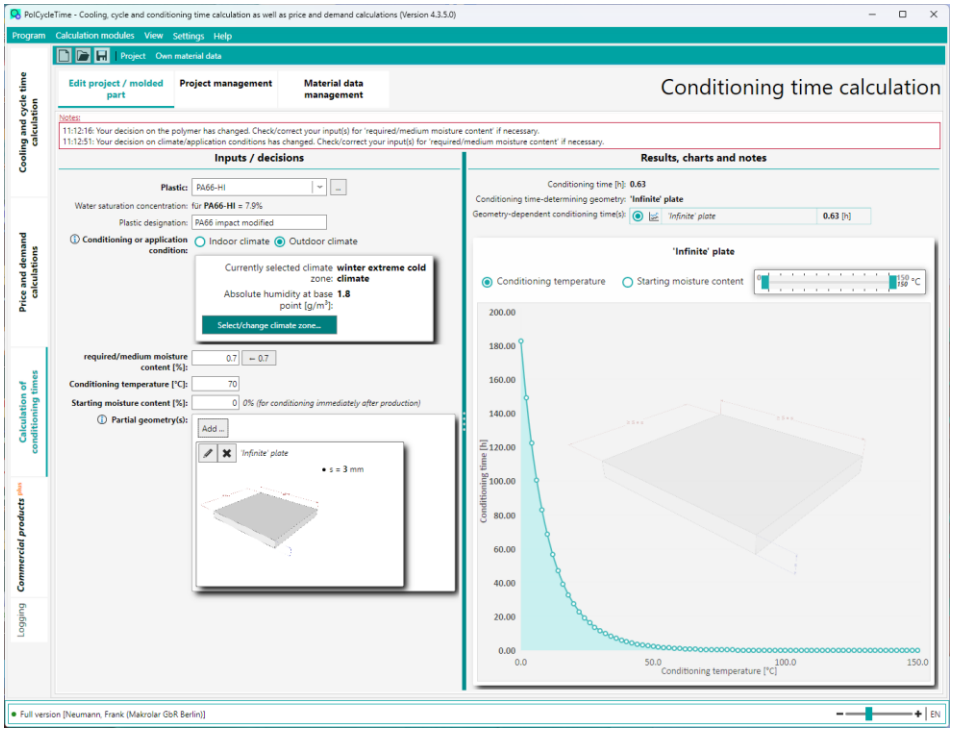


Figure 34: Inputs, results and chart of the conditioning time

> **Note:** The notes list at the top reports when a changed decision affects other inputs (e.g. “Your decision on the polymer has changed. Check/correct your input(s) for ‘required/medium moisture content’ if necessary.”).

5.4 Project management and own material data

Project data, saving and printing work as in chapter 3. Under **“Material data management”** or the **“Own material data”** menu you create your own polyamides: name, water saturation concentration, base diffusion coefficient at 23 °C, activation energy and a comment on the source. An additional auxiliary calculation is available in the input window for the water saturation concentration and the base diffusion coefficient.

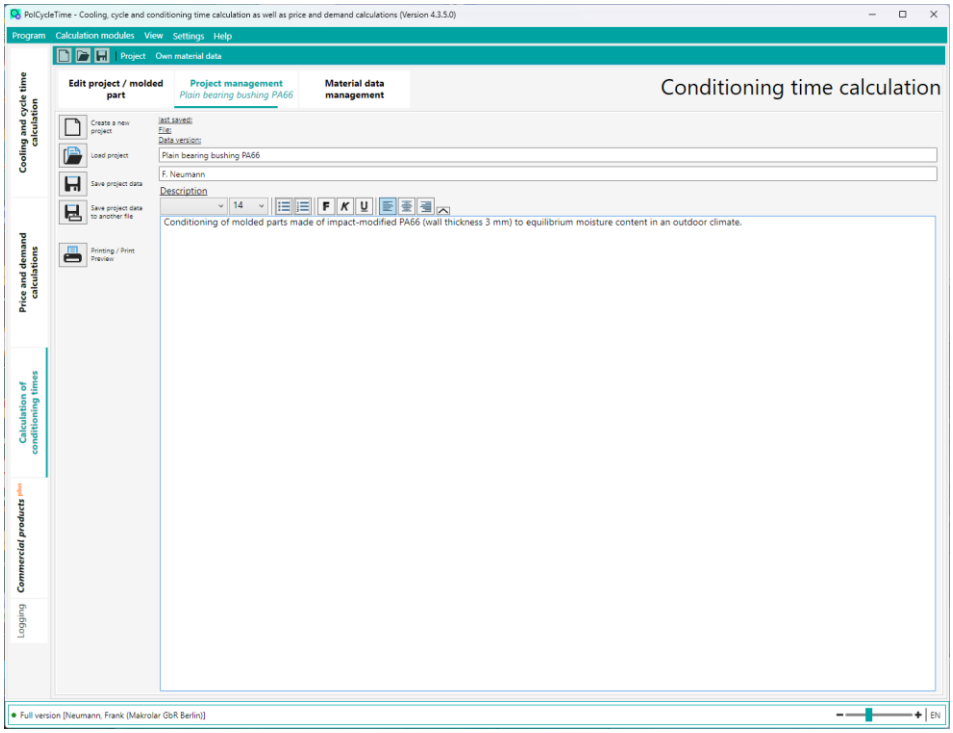


Figure 35: Project management of the conditioning time calculation

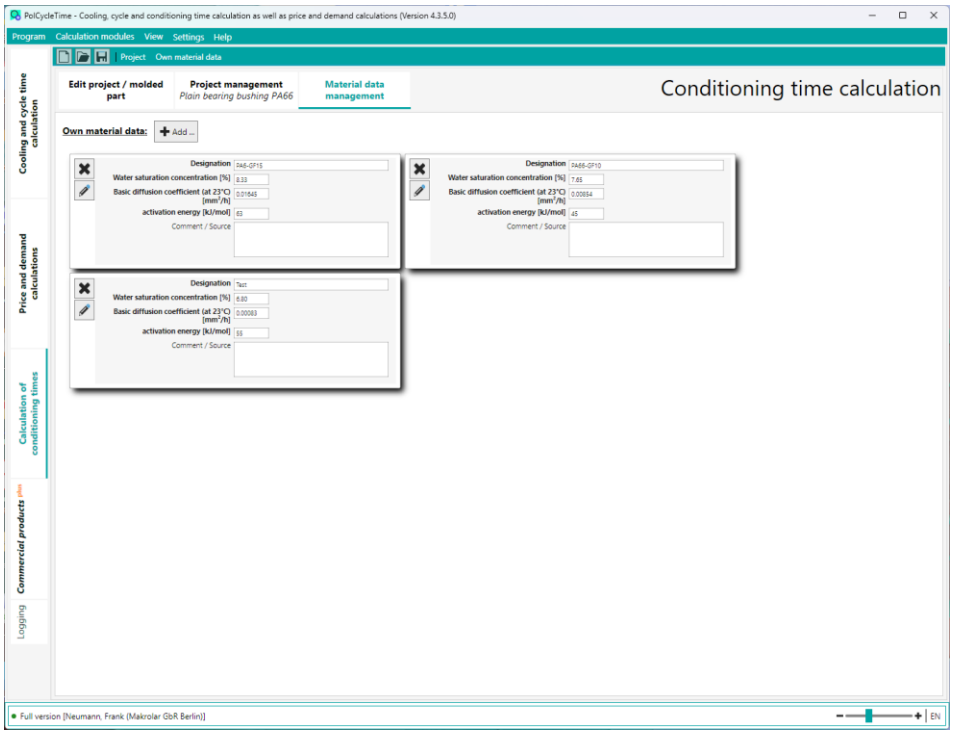


Figure 36: Own material data for conditioning

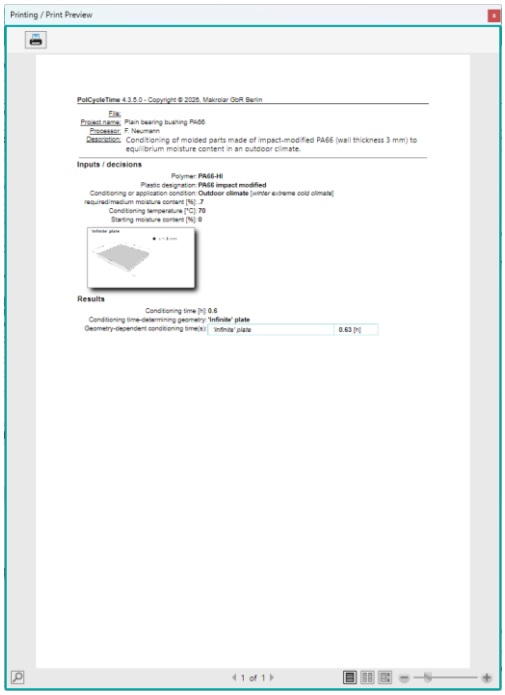


Figure 37: Print preview of the conditioning time calculation

6 Calculation modules

The **“Calculation modules”** menu contains the auxiliary calculation **“Melt density…”**. Select a **Polymer** and, if required, use **“+”** to add additives with their mass fraction. PolCycleTime shows the specific volume of the polymer melt and calculates the **melt density**. Example: (ABS+PC) with 20 % glass fibers → 1.190 g/cm³.

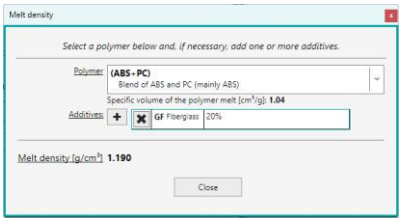


Figure 38: Calculation module "Melt density"

The calculation uses the specific volume of the polymer melt and the densities of the additives from the internal database. The same calculation is available in the residence time calculation (section 3.8) via the **"…"** button next to the melt density.

7 Menus

Menu	Commands
Program	**Exit Program**; **Info about…**
Calculation modules	**Melt density…** (chapter 6)
View	Switch between **Cooling and cycle time calculation**, **Price and demand calculations**, **Calculation of conditioning times** and **Commercial products**; **Original size (100%)**; results change view.
Settings	**Server connection…**; **Activate the license…**; **Reset the license…**; **Options…**; **Language/Sprache…**
Help	**Check for software update…**; **To our homepage…**; **Register for the software…**; **View online help**; local help for the modules **Cooling and cycle time** (F1) and **Price and demand calculation** (F2) as well as for the commercial products database.
Project (module bar)	Create a new project, load, save, save as, **print / print preview**
Extras (cycle time)	**Residence time calculation**
own data (cycle time)	Add a polymer, an additive or an injection moulding machine
Project/Moulded part, Variants, View (calculation)	Edit basic data, print / print preview; add a new variant (empty or with the wizard); expand/collapse the groups of all variants.

8 Tips and frequently asked questions

Question	Answer
Why is no cycle time shown?	Inputs are still missing. Section headings marked red show where something is missing; often there are still undecided check boxes (filled square).
Which geometry do I have to enter?	All areas that can determine the cooling time: the thickest wall of the part and thick runner cross-sections. The program selects the longest cooling time.
How do I transfer the cycle time to the calculation?	Enter the calculated value in the variant wizard or in the "Machine running time and cycle time" section.
How do I compare mould variants?	Copy a variant, change the number of cavities and the mould costs and compare the total unit costs side by side.
What do the values with ⓘ mean?	These are orientation values derived from your other inputs. Use "←" to adopt them.

Question	Answer
How accurate is the calculated cooling time?	For the thermodynamic moulding compound data, deviations of the cooling time of no more than ± 10 % are expected (section 3.11). To minimize the cycle time, an additional optimization under production conditions is recommended.
My material is not in the list.	Create it as an own polymer or as own material data (sections 3.9 and 5.4).