## LOI
### THERMPROCESS GMBH

Manual

# - Hardenability -
## Optimizing the Heat Treatment
**©2009**

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# Contents

# Hints for using

First here follow some hints for using the software.

Hardenability database can be ordered as a single or a multi user version.

The database is registrated with one easy e-mail or fax to our office.

In a multi user version there are some conditions to be noticed to get fast and serious simulation results.

The data rate in the network should be 100 mbit/sec. as a minimum to get results as fast as in a single user version. If the data rate is less than 100 mbit/sec. the answering times will slow down.

A network installation is to be preferred if you want enter a lot of common simulations into the database. If you use the database only to get fast simulation results using always the same two or three calculations and modifying them in only some parameters it would be better to install the multi user version as many single user versions local on the clients to get more speed.

If you are not sure please contact our support. We will gladly inform you.

Please have much fun and succes using Hardenability database.

# Hints for installing the single user version

You ordered a single workstation version of Hardenability database that must be registrated with license code once a time. Please follow all steps to install the software correctly.

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**Installation of Hardenability database on a single workstation**

1.  Start windows on your single workstation and open the program manager.

2.  Insert CD-Rom into to CD-Rom-drive.

3.  Choose option "File", "Execute" in program manager.

4.  Enter "x:\setup.exe" ("x" stands as a letter for your CD-Rom-drive) and press the Enter-key.

5.  Follow all commands on the screen. The directory for installation must be a local one.

6.  During the installation a new programm group "Hardenability" will be built. In this program group two symbols for Hardenability database and Hardenability help will be created.

7.  For online registration on the single workstation please contact LOI, Essen, Germany. For getting the registration code it is important to message the computer code displayed in the license window.

8.  After registration Hardenability database is ready to start on this workstation.

In all screens of Hardenability database there is a windows help ("F1") available.

# Hints for installing the multi user version

You ordered a network version of Hardenability database. For this software you have install common data on your network server an local programs on your clients. After installation of the clients a registration is necessary to use the database. After starting the database for the first time on a client you will be guided through that registration. In Win'NT/2000/XP you have to be an administrator on this client to registrate the database.

**Installation of Hardenability common data on the server**

1.  Please insert the purchased CD into your CD-Rom-drive.

2.  Choose option "File", "Execute" in program manager.

3.  Enter "x:\setup.exe" ("x" stands as a letter for your CD-Rom-drive) and press the Enter-key.

4.  Follow all commands on the screen. The directory for installation must be on your server. Users must have all rights on this directory.

**Installation of Hardenability database on the clients**

1.  Start windows on your single workstation and open the program manager.

2.  Insert CD-Rom into to CD-Rom-drive.

3.  Choose option "File", "Execute" in program manager.

4.  Enter "x:\setup.exe" ("x" stands as a letter for your CD-Rom-drive) and press the Enter-key.

5.  Follow all commands on the screen. The directory for installation must be a local one.

6.  During the installation a new programm group "Hardenability" will be built. In this program group two symbols for Hardenability database and Hardenability help will be created.

7.  After the first start you have to enter a directory as the data path on the server where you have installed the common data before.

8.  For online registration on the single workstation please contact LOI, Essen, Germany. For getting the registration code it is important to message the computer code displayed in the license window.

9.  After registration Hardenability database is ready to start on this workstation.

10. To use the database on other clients please repeat steps 1 to 8 of this client installation.

In all screens of Hardenability database there is a windows help ("F1") available.

# Basics

## Welcome to Hardenability HTML-help

Contact:

[www.loi.de](www.loi.de)

**General use**

Database CaseHarding corresponds to the common windows standard for user interfaces.

The user is able to work intuitive. The meaning of all menu items result in their unique notations.

In the top of all data windows a toolbar with frequently used functions appears. These functions can be called up by their items or by menu.

**First start**

After the first start regularly a window appears, that is asking for the correct data path. This is the directory in which the material data are stored. On the right side button the correct data path can be selected.
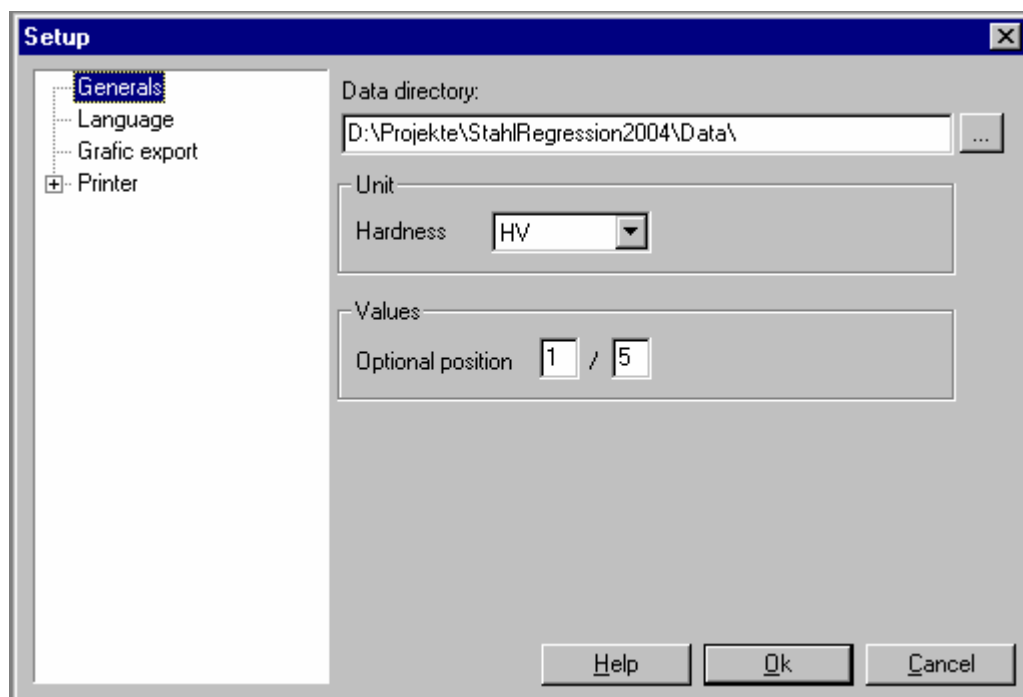


In this window the data path and the physical unit for displaying the hardness can be determined. With the optional position the user can determine one auxiliary position in the part to be calculated in addition to surface, core and the middle between.

Also the user can set the language. Normally german language is set.

At least the user can set up two printers for text prints and for graphic prints.

In case that after determining the data path an error message occurs that an index file is corrupted or missing, the window for reorganization appears afterwards. The button OK must be pressed to start the reorganisation. Thereafter the program is ready for use.

If some settings shall be changed later on one can select this options window with menu "Extras - Options".

**Program start**

After starting the program the first data screen appears. This screen with treeview and browserlist is the main entrance into the program.

Every calculation data can be selected in the right browserlist double clicking the left mouse button. Then the data are displayed in a formular view.



**Tool bar**

In the top of all data windows a tool bar appears. Frequently used functions for the program can be called up with icons. The icons are activated by mouse click.

The icons only are activated in those data windows where this function is active.



With this button the current record in the data window will be printed. A preview appears on the screen. From this preview the printing can be confirmed or cancelled.



With this button the user can switch between the list view and the form view in the current data window.

With this button the current data field is saved in the Windows clipboard. The current data field is deleted on the screen.



With this button the current data field is saved in the Windows clipboard. The current data field is not deleted on the screen.



With this function data from the windows clipboard will be inserted into the record or the document at the current cursor position.



With this button the user can skip to the record which is the first in the current order of the data window.



With this button the user can skip to the record which is the previous in the current order of the data window.



With this button the user can skip to the record which is the next in the current order of the data window.



With this button the user can skip to the record which is the last in the current order of the data window.



With this button the search window for the relevant data window is displayed.



With this button the search filter is toggled off. The search filter is automatically toggled on after each data search to reduce the shown data.

With this button a new blank record in the current data window is created. For this new record the edit mode is activated. The edit mode will be finished by mouse click on the activated button "OK". The new record will be saved. The edit mode is cancelled by mouse click on the activated button "Cancel". The new record won't be saved.

With this button the edit mode for the current record in the data window is activated. The edit mode will be finished by mouse click on the activated button "OK". The changed record will be saved. The edit mode is cancelled by mouse click on the activated button "Cancel". The changed record won't be saved.

With this button the current record in the data window is copied. For this copied record the edit mode is activated. The edit mode will be finished by mouse click on the activated button "OK". The copied record will be saved. The edit mode is cancelled by mouse click on the activated button "Cancel". The copied record won't be saved.

With this button the current record in the data window is deleted. The deletion cannot be cancelled. Records deleted by mistake have to be entered again.

**Menus**

The architecture of the menus corresponds with usual windows standards. Mostly all menu items can be activated by hot keys.

- Menu "File"
- Menu "Edit"
- Menu "View"
- Menu "Extras"
- Menu "Window"
- Menu "Help"

**Close**

With this menu item the current data window is closed and the next data window further down is activated. If no other data window is opened the blank application screen is displayed.

**Close all**

With this menu item all data windows are closed. The blank application screen is displayed.

**Next**

With this menu item it is possible to jump into the next program window if more than one window is opened.

**Previous**

With this menu item it is possible to jump into the previous program window if more than one window is opened.

**Cascade**

With this menu item all programm windows are displayed in a cascading style.

**Tile horizontally**

With this menu item all programm windows are displayed one upon the other from top to bottom.

**Tile vertically**

With this menu item all programm windows are displayed side by side from left to right.

**Print**

With this menu item the current record in the data window will be printed. In some cases a preview appears on the screen. From this preview the printing can be confirmed or cancelled.

**Exit**

With this menu item the current application will be finished. The application itself, all data windows and all opened data are closed.

The Windows desktop appears on the screen.

**Cut**

With this function the current data field is saved in the Windows clipboard. The current data field is deleted on the screen.

**Copy**

With this function the current data field is saved in the Windows clipboard. The current data field is not deleted on the screen.

**Paste**

With this menu item data from the windows clipboard will be inserted into the record or the document at the current cursor position.

**New data**

With this button a new blank record in the current data window is created. The edit mode is activated for this new record. The edit mode is finished by mouse click on the activated button "Ok". The new record will be saved. The edit mode is cancelled by mouse click on the activated button "Cancel". The new record won't be saved.

**Edit data**

With this function the edit mode for the current record in the data window is activated. The edit mode is finished by mouse click on the button "Ok". The changed record will be saved. The edit mode is cancelled by mouse click on the button "Cancel". The changed record won't be saved.

**Copy data**

With this function the current record in the data window is copied. For the copied record the edit mode is activated. The edit mode is finished by mouse click on the button "Ok". The copied record will be saved. The edit mode is cancelled by mouse click on the button "Cancel". The copied record won't be saved.

**Delete data**

With this function the current record in the data window is deleted. The deletion cannot be cancelled. Records deleted by mistake have to be entered again.

**Search data**

With this function the search window for the relevant data window is displayed.

**First record**

With this function the user can skip to the first record in the data window occurring in the current order.

**Previous record**

With this function the user can skip to the previous record in the data window occurring in the current order.

**Next record**

With this function the user can skip to the next record in the data window occurring in the current order.

**Last record**

With this function the user can skip to the last record in the data window occurring in the current order.

**Navigation bar**

With this function the navigation bar (treeview) is toggled on and off.

**Content and index**

With this function the help display is activated.

**About**

With this menu item the information screen about the program and the applied version appears.

# Introducion

## Introducion

The thermal treatment of steel and the characteristics which can be stopped thereby are influenced by a multiplicity of different parameters. Excluding certain physical properties are almost required by the construction over the purchase and the finishing technique up to quality control or alternatively hardness specifications are made.

The thermal treatment department must determine then a thermal treatment sequence, which leads to the required values. This thermal treatment sequence must consider all characteristic-influencing factors for the implementation of the specifications and contain the thermal treatment parameters resulting from it. In many cases the specification of these factors is based on empirical values and by the job planning after best knowledge is determined.

Into that firmness areas are determined to the relevant sets of rules such as DIN, VdTUEV specifications, SE material pages etc., which in most cases permit a quite large spread by most diverse factors of influence. In the concrete definition of the thermal treatment parameters however the specification in sets of rules is at best reference values, particularly since the specific characteristics of the different heat treatment facilities remain completely unconsidered.

By the increasing application of the computer technology it was possible in the past to enter and mathematically analyse large quantities of data from many thermal treatment processes with their results. On the basis of these analyses regression equations were developed for the determination by mechanical characteristics after the thermal treatment, which the bases for all calculated in this program thermal treatment results form.

The actual calculation takes place in several mandatory consecutively following steps. Due to the too speziefizierenden dimension of the component which can be cooled down and the deterrent conditions cooling curves between edge and core are calculated. The cooling speed is correlated with consideration of the current chemical composition with the structure quantities which can be expected. This relationship supplies a first important predicate about the structure composition after deterring. In a next step the hardness values of the structure components are calculated and determined over the quantities the total hardness according to deterring.

The hardness values of the structural constituents depend both on the chemical composition and on the cooling rate of the Beuteils with deterring. Both factors are considered with the calculation.

# Calculation

## Input calculation

Every calculation data can be selected in the right browserlist double clicking the left mouse button. Then the data are displayed in a formular view.

In the left tree view additional information to the displayed calculation can be selected.



Above the tree view the material name and material number are displayed in every part of the program. So every time it is possible to get the reference to displayed informations.

## New calculation

Own material data can be added in different ways:

- Click button "new" in tool bar
- Select menu "Edit - new"

All empty fields can be filled with own data. Almost every field requires an input. For some fields selections are possible.

In the above window all data for the calculation are entered. In all fields which are neccessary for the calculation a precheck is done. So it is sure that only calculations can be started in which the data are proved and do not exceed the limitations of the mathematical model.

In the upper part of the window the general describing informations are entered. These are the material name, the material number and an additional description. If a material name or material number is entered it is possible to select the chemical composition out of a list which is displayed by clicking the button right near the material number.

In the next part of the window the chemical composition is determined. In this analysis the limits of the mathematical model must be noticed. The elements C, Si, Mn, Cr, Mo, Ni and V are considered and are necessary for every successful calculation. If one of the elements S, P or Cu is filled the liquidus- and solidus-temperatures are calculated.

In the third part of the window the component with its geometry (shape and dimension) and its temperature at process start is defined. Depending on the shape it is possible to enter the diameter for round shapes, the thickness for plates or the inner and outer diameter for pipes.

In the lower part of the window the heat treatment procedure is defined in maximum four steps (hardening, quenching, tempering and cooling). In the selection box directly above a standard heat treatment profile can be selected.

All steps are described with the media, the media temperature, a possible temperature ramp, the ending temperature for the step in components core and the following holding time. After entering these information the program proves the input, which among other things depends on the chemical composition and components dimension.

With a left mouse click on button "Cancel" the input can be stopped at every moment, - no data will be stored. With a left mouse click on button "Ok" all data are stored.

After clicking the button "Ok" some more checks will be done. In case of incorrect entries an error message appears. After the acknowledge of this message the cursor is placed at the wrong input.

If all data are correct the calculation of the heat treatment cycle starts. The progress of this calculation is displayed in an information window. When the calculation is finished the results are stored in the calculation sheet.

## Edit calculation

Calculations can be modified. The calculation can be modified in different ways:

- Click button "edit" in tool bar
- Select menu "Edit - edit data"

All empty fields can be filled with own data. Almost every field requires an input. For some fields selections are possible. If a material name or material number is entered it is possible to select the chemical composition out of a list which is displayed by clicking the button right near the material number.

With a left mouse click on button "Cancel" the input can be stopped at every moment, - no data will be stored. With a left mouse click on button "Ok" all data are stored.

After clicking the button "Ok" some more checks will be done. In case of incorrect entries an error message appears. After the acknowledge of this message the cursor is placed at the wrong input.

If all data are correct the calculation of the heat treatment cycle starts. The progress of this calculation is displayed in an information window. When the calculation is finished the results are stored in the calculation sheet.

## Copy calculation

Calculations can be copied. The calculation can be copied in different ways:

- Click button "copy" in tool bar
- Select menu "Edit - copy data"

All empty fields can be filled with own data. Almost every field requires an input. For some fields selections are possible. If a material name or material number is entered it is possi-

ble to select the chemical composition out of a list which is displayed by clicking the button right near the material number.

With a left mouse click on button "Cancel" the input can be stopped at every moment, - no data will be stored. With a left mouse click on button "Ok" all data are stored.

After clicking the button "Ok" some more checks will be done. In case of incorrect entries an error message appears. After the acknowledge of this message the cursor is placed at the wrong input.

If all data are correct the calculation of the heat treatment cycle starts. The progress of this calculation is displayed in an information window. When the calculation is finished the results are stored in the calculation sheet.

## Delete calculation

Calculations can be deleted. The calculation can be deleted in different ways:

- Click button "delete" in tool bar
- Select menu "Edit - delete data"

Deleting any calculation is to be confirmed with the button "Ok".

## Print calculation

Calculations can be printed. The calculation can be printed in different ways:

- Click button "print" in tool bar
- Select menu "File - print"

Then the window for windows printer selection appears.

# Results

**Results**

The results of calculating the heat treatment cycle can be selected in the left tree view. There are following possibilities:

- Mechanical properties
- Physical properties
- Transformation
- Heat treatment
- Optimizing

**Mechanical properties**

The mechanical properties include …

- Table results of structure, hardness and mechanical properties

- Hardness shape as diagram

- Tensile strength/yield strength as diagram

- Elongation/necking as diagram

- Bending fatigue strength as diagram

## Table results

| Analysis |
| --- |
| 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni; |

**Part and treatment**
Round shape; Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h -> Air

| Structure / properties | | Surface | Middle | Core | 1/5 ø |
| --- | --- | --- | --- | --- | --- |
| Martensite | % | 34 | 0 | 0 | 7 |
| Bainite | % | 66 | 95 | 93 | 89 |
| Ferrite / Pearlite | % | 0 | 5 | 7 | 4 |
| Hardness before tempering | HV | 466 | 355 | 345 | 377 |
| Hardness after tempering | HV | 315 | 285 | 283 | 291 |
| Tensile strength | MPa | 960 | 866 | 862 | 885 |
| Yield strength | MPa | 806 | 692 | 685 | 715 |
| Bending fatigue strength | MPa | 517 | 471 | 468 | 480 |
| Elongtion | % | 15 | 16 | 16 | 16 |
| Necking | % | 55 | 56 | 56 | 56 |

In this screen the results for the calculated structure, hardness and mechanical properties are displayed. The results are calculated for components surface, core and the middle between. In the right column the results for the optional position are displayed.

## Hardness shape



Hardness shape: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h
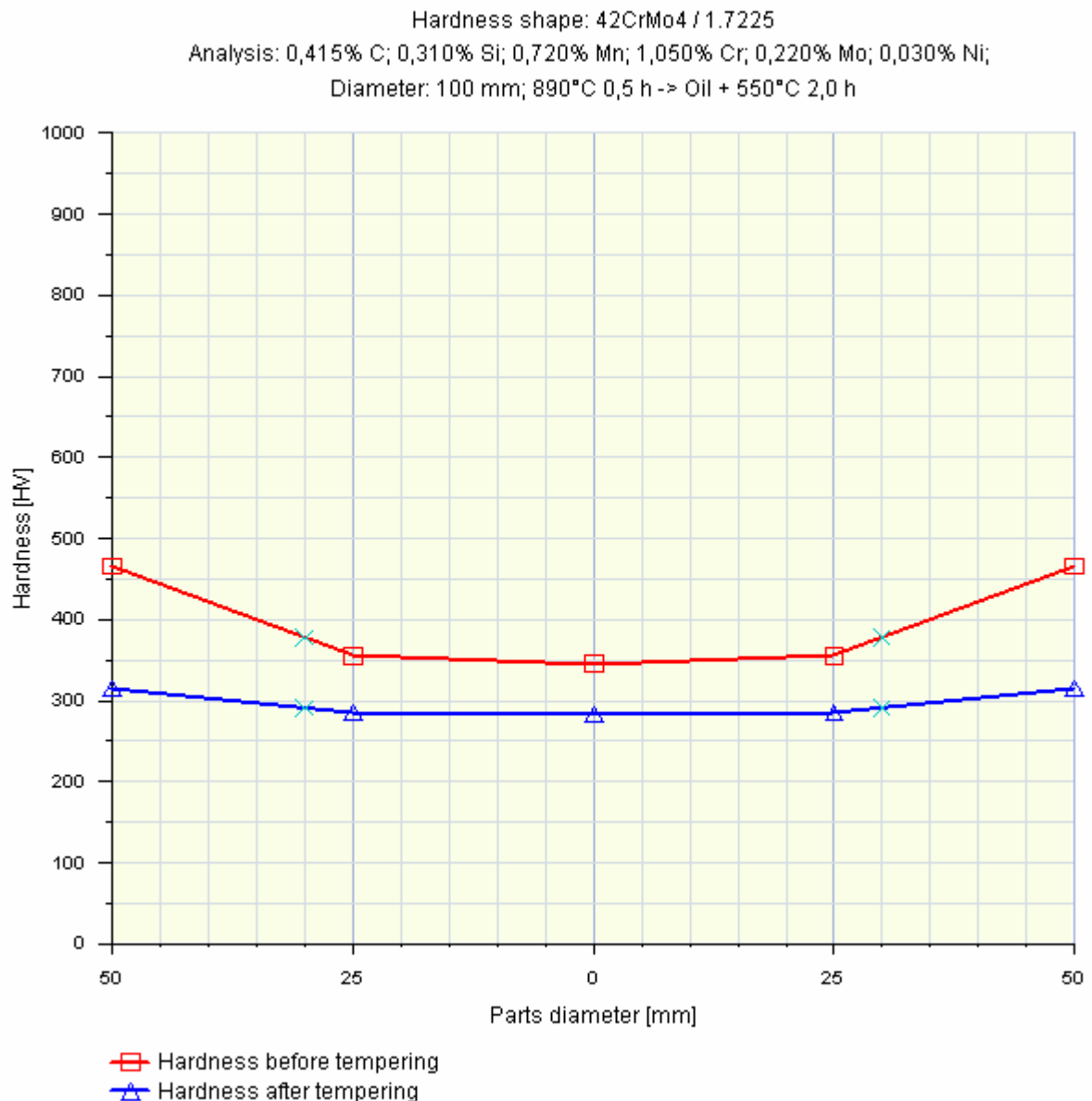
Based on the selected calculation the simulated hardness shapes are displayed in a diagram as lines. The hardness shapes before and after tempering are displayed. Elements for drawing the lines are hardness at surface, core and at the middle between.

The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Tensile strength/yield strength

Tensile strength / Yield strength: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h



Based on the selected calculation the simulated shapes for tensile strength and yield strength are displayed in a diagram as lines. Elements for drawing the lines are strength at surface, core and at the middle between.

The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.
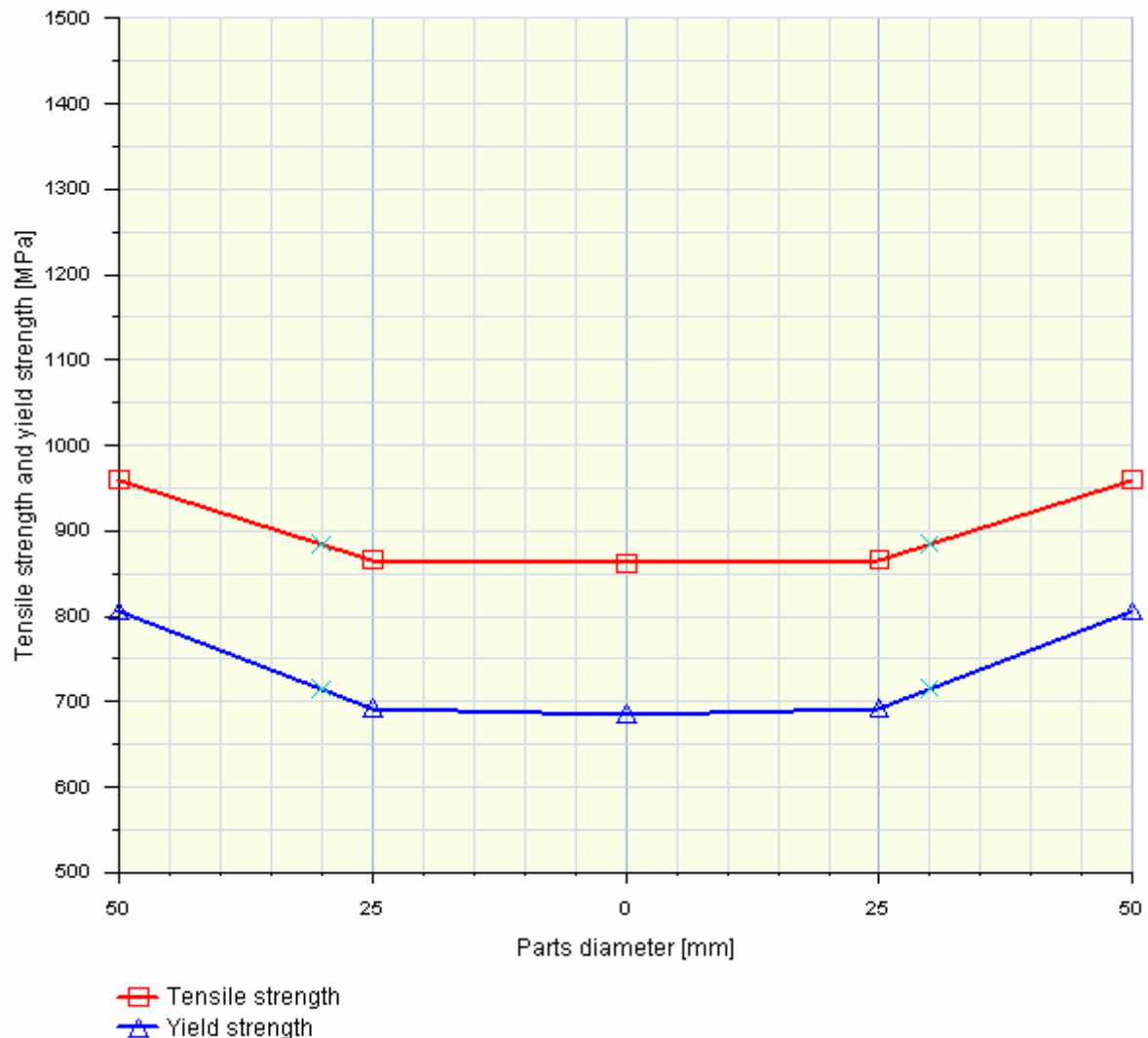
By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Elongation/necking



Elongtion / Necking: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h

Based on the selected calculation the simulated shapes for elongation and necking are displayed in a diagram as lines. Elements for drawing the lines are elongation and necking at surface, core and at the middle between.
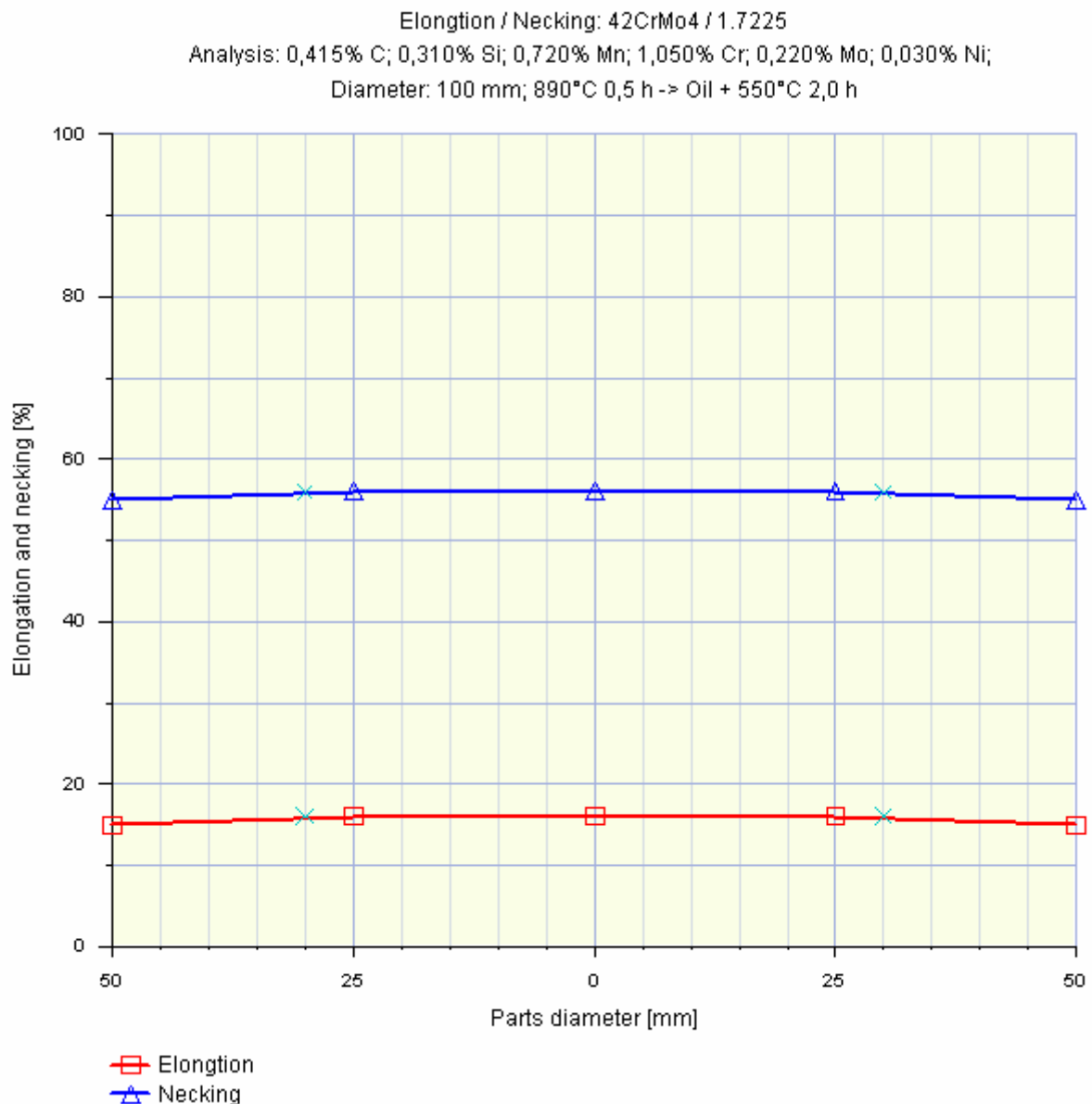
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Bending fatigue strength



Bending fatigue strength: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h

Bending fatigue strength

Based on the selected calculation the simulated shape for bending fatigue strength is displayed in a diagram as a line. Elements for drawing the line are bending fatigue strength at surface, core and at the middle between.
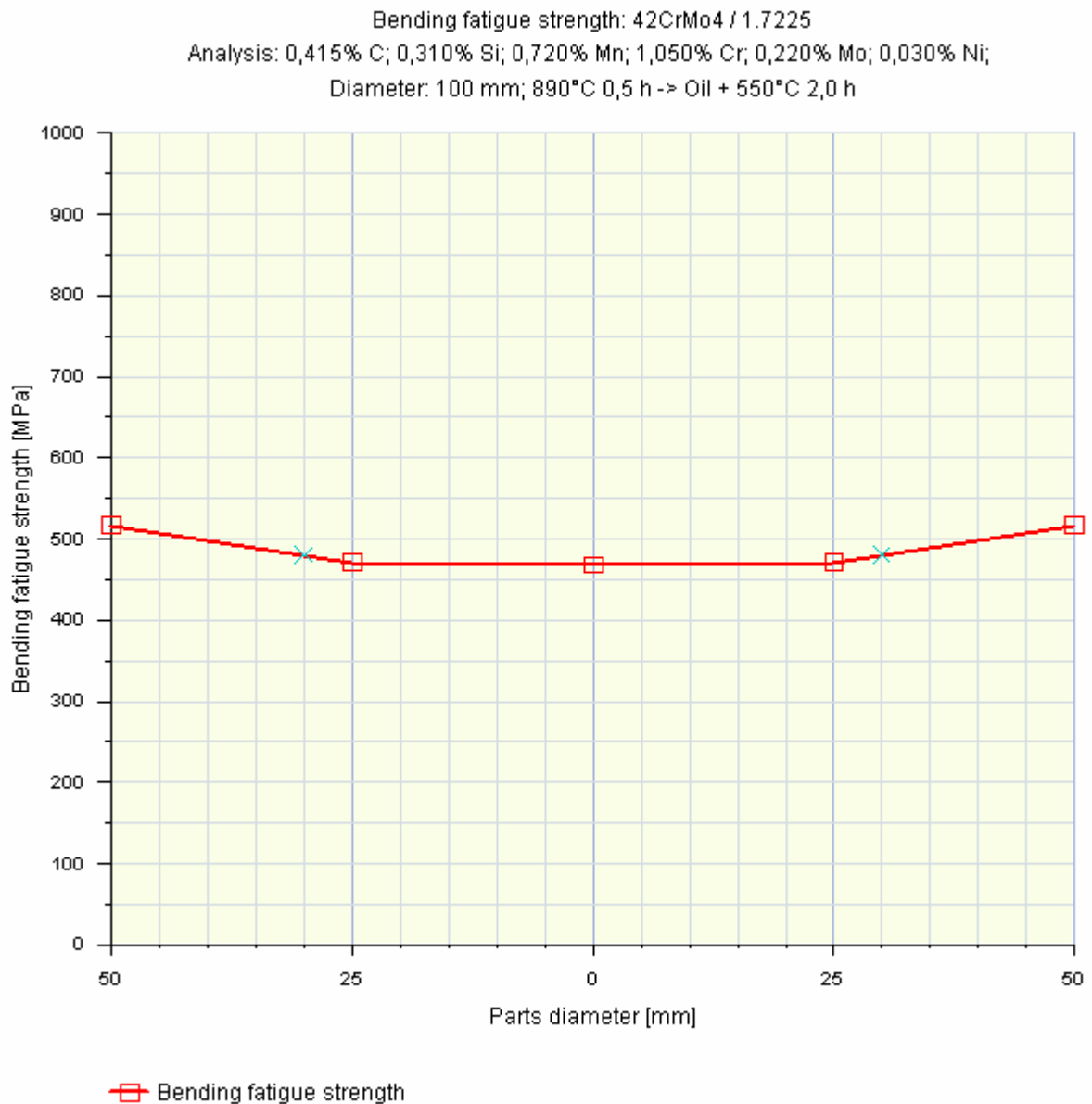
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

**Physical properties**

The physical properties include …

- Density as diagram

- Thermal expansion as diagram

- Heat conductivity as diagram

- Heat capacity as diagram

## Density



Density: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
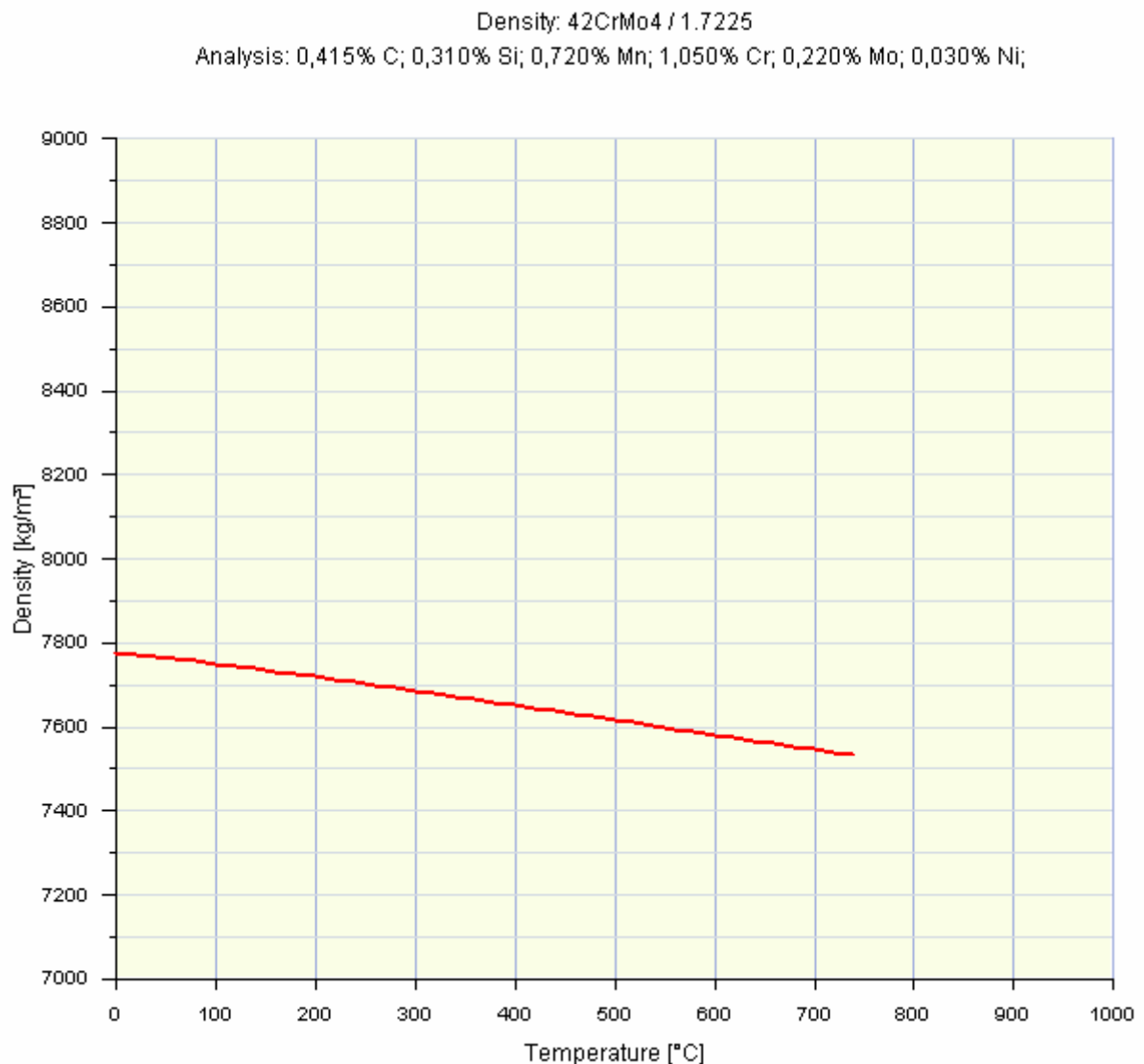
The ratio mass/volume describes the density. Therefore it is:

$$\frac{mass[kg]}{volume[m^3]} = density$$

Density is material specific and depends on the temperature. The density depending on a temperature and on a specific material can be calculated with a formula by Dr. Eckstein. Under the consideration of the valid boundaries the formula is solved in this program.

The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Thermal expansion

Thermal expansion: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;



Steel expands under higher temperatures. The thermal expansion is proportional to the thermal expansion coefficient. The thermal expansion coefficient depending on a temperature and on a specific material can be calculated with a formula by Dr. Eckstein. Under the consideration of the valid boundaries the formula is solved in this program.
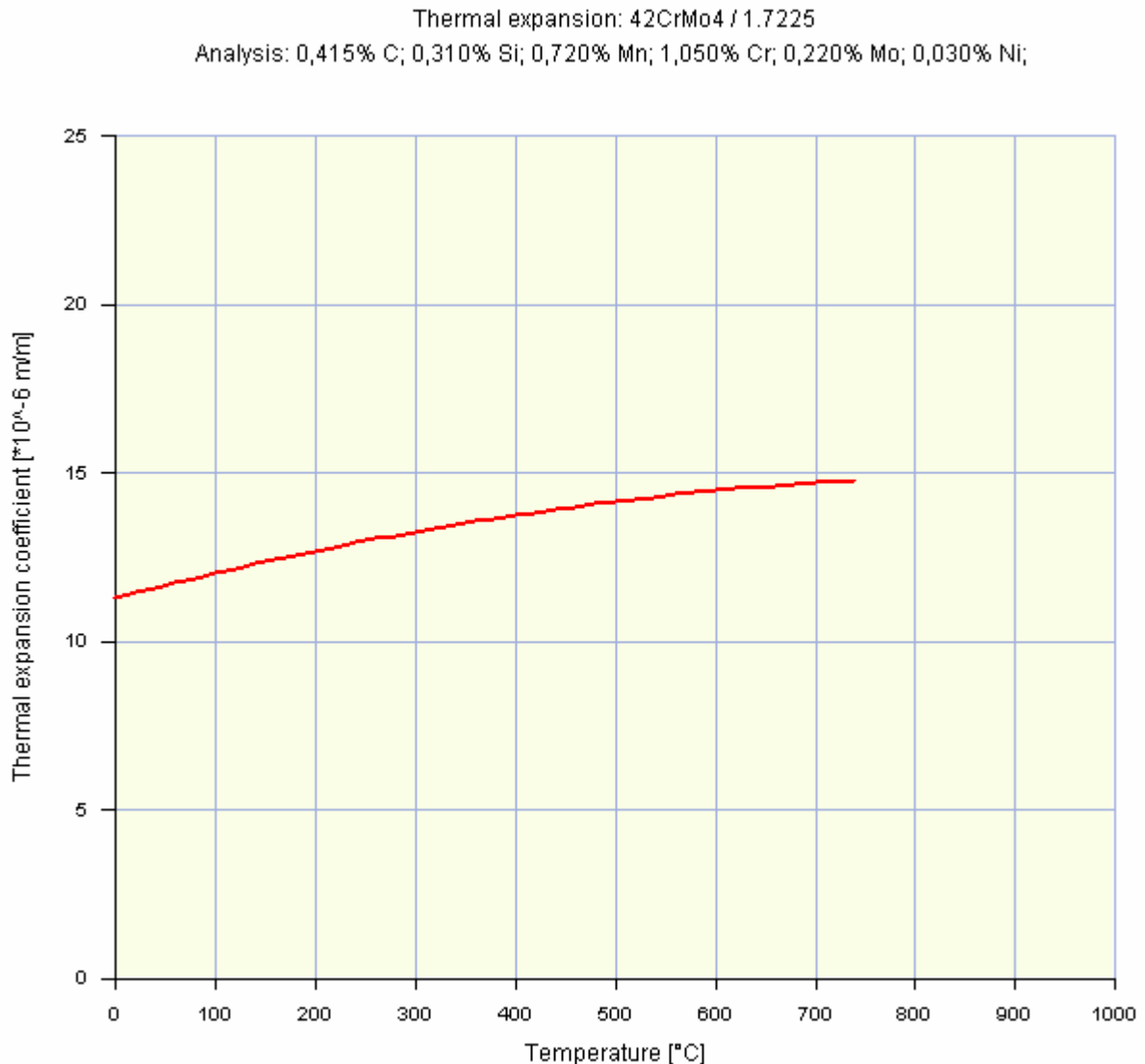
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Heat conductivity

Heat conductivity: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;



Because of their structure metallurgical materials are good electrical and thermal convectors. The heat conductivity depending on a temperature and on a specific material can be calculated with a formula by Dr. Eckstein. Under the consideration of the valid boundaries the formula is solved in this program.
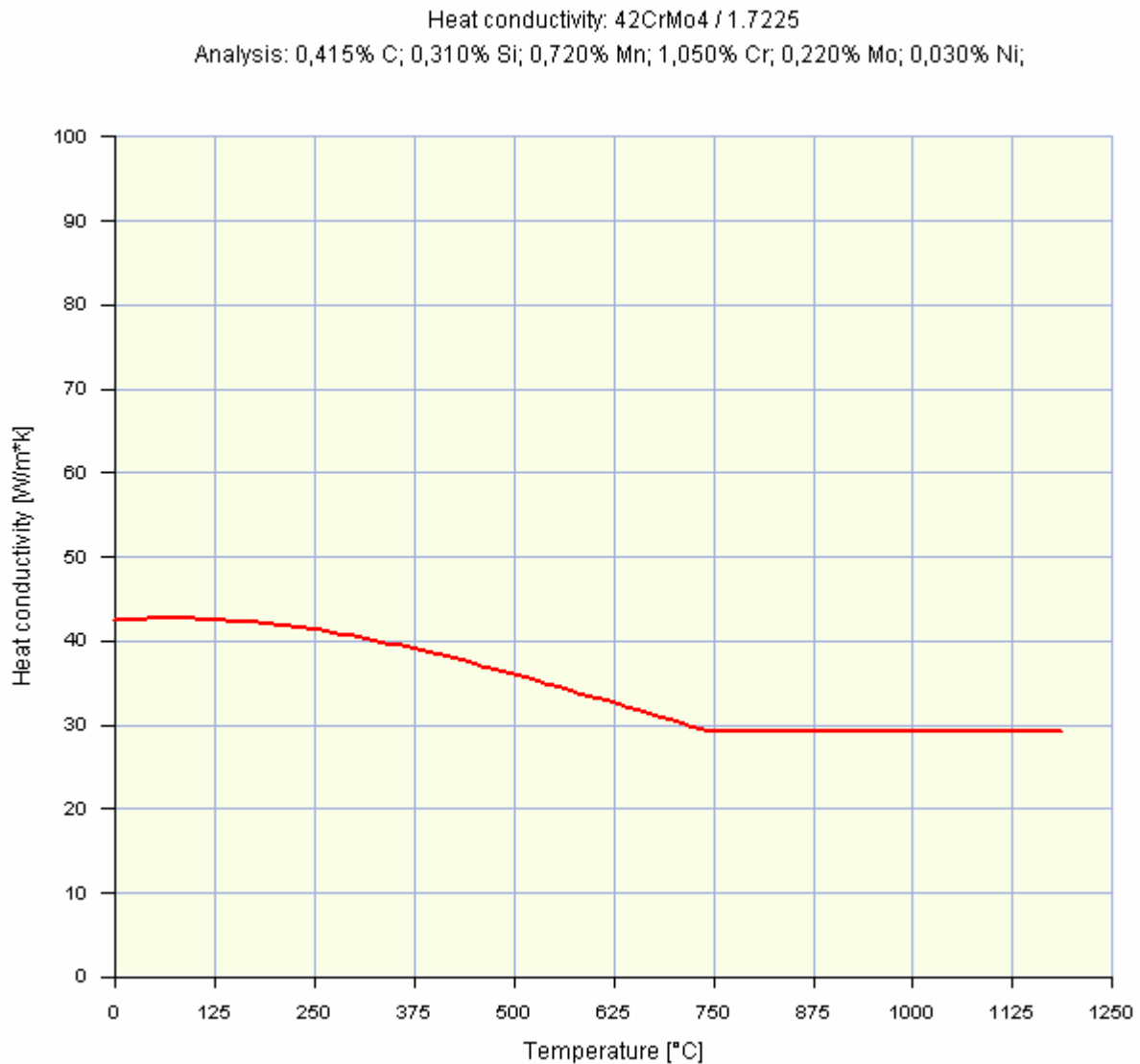
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

**Heat capacity**



Heat capacity: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;

The specific heat capacity describes what amount of heat a body of 1 kg mass absorbs if its temperature increases for $\Delta\vartheta$ 0 1°C. The heat capacity depending on a specific temperature can be calculated with a formula by Dr. Richter. Under the consideration of the valid boundaries the formula is solved in this program.
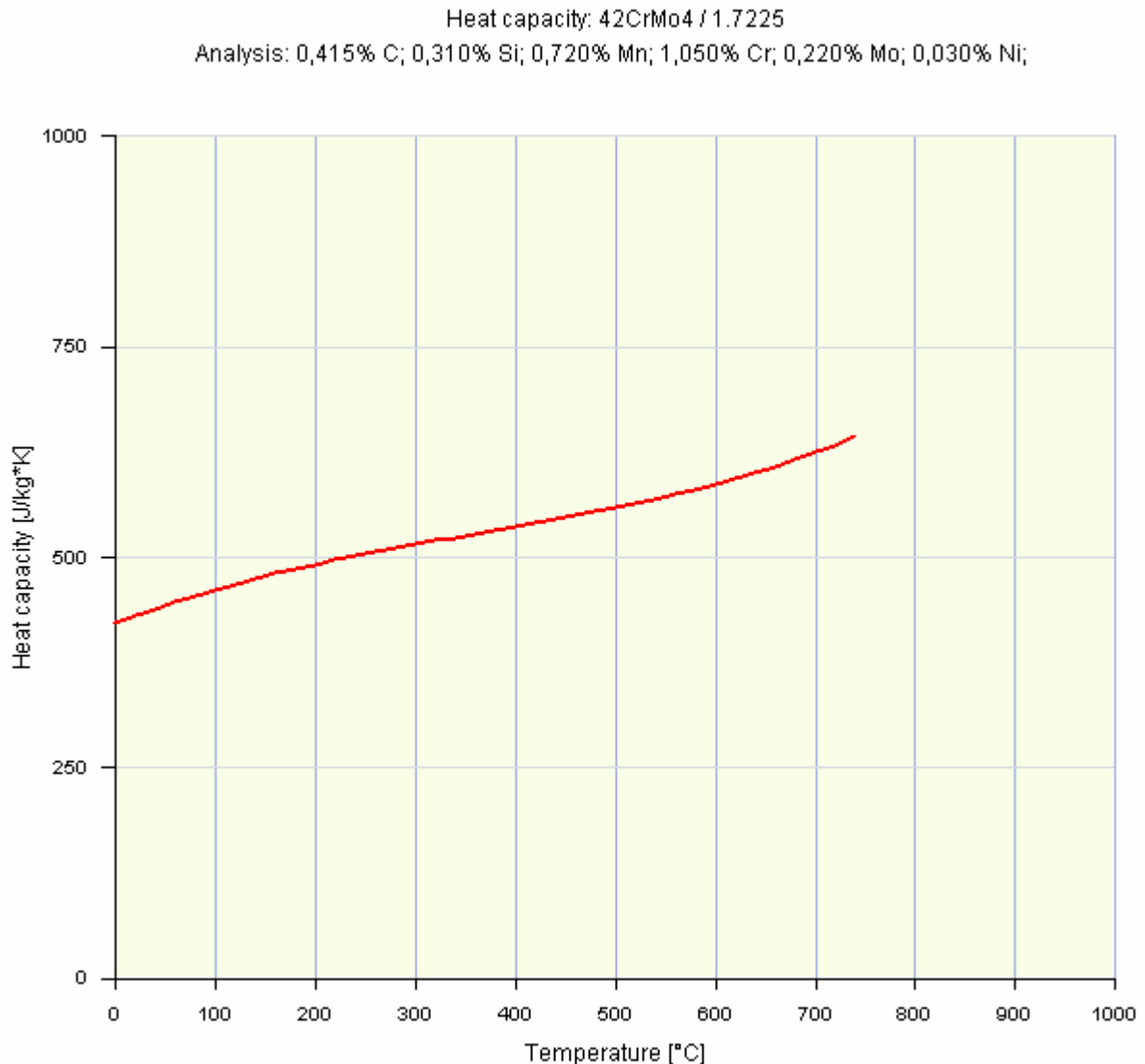
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

**Transformation**

The transformation includes …

- CCT-diagram

- CCT-diagram with cooling curve

- Transformation temperatures as diagram

- Structure diagram

- Amount structure diagram

- Tempering diagram(1)

**CCT-diagram**



CCT-diagram: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Austenitizing: 890°C 0,5 h

| t85-time | - upper critical cooling: | 16,6 s |
|---|---|---|
| | - pearlite formation: | 93,0 s |
| | - lower critical cooling: | 785,4 s |

A continuous time-temperature-diagram describes the desequilibrium of the microstructure for a material depending on the cooling rate. Under consideration of the mathematical model the continious time-tempering-diagram is drawn.

The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.
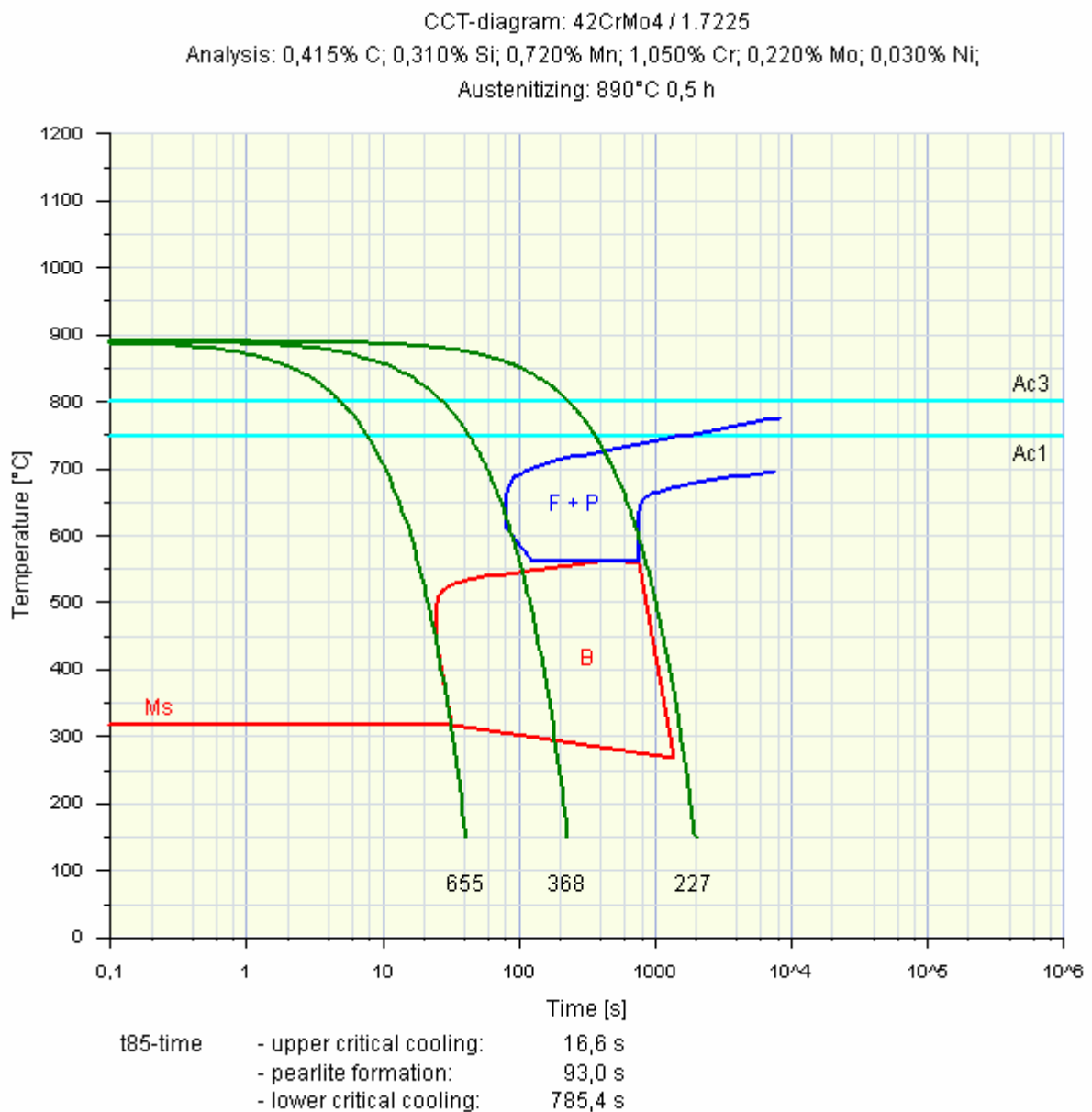
With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## CCT-diagram with cooling curve



CCT-diagram + Cooling curve: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil

| t85-time | - Surface: | 20,9 s |
| | - Core: | 51,0 s |

A continuous time-temperature-diagram describes the desequilibrium of the microstructure for a material depending on the cooling rate. Under consideration of the mathematical model the continious time-tempering-diagram is drawn. In this diagram also the calculated quenching curve is displayed.
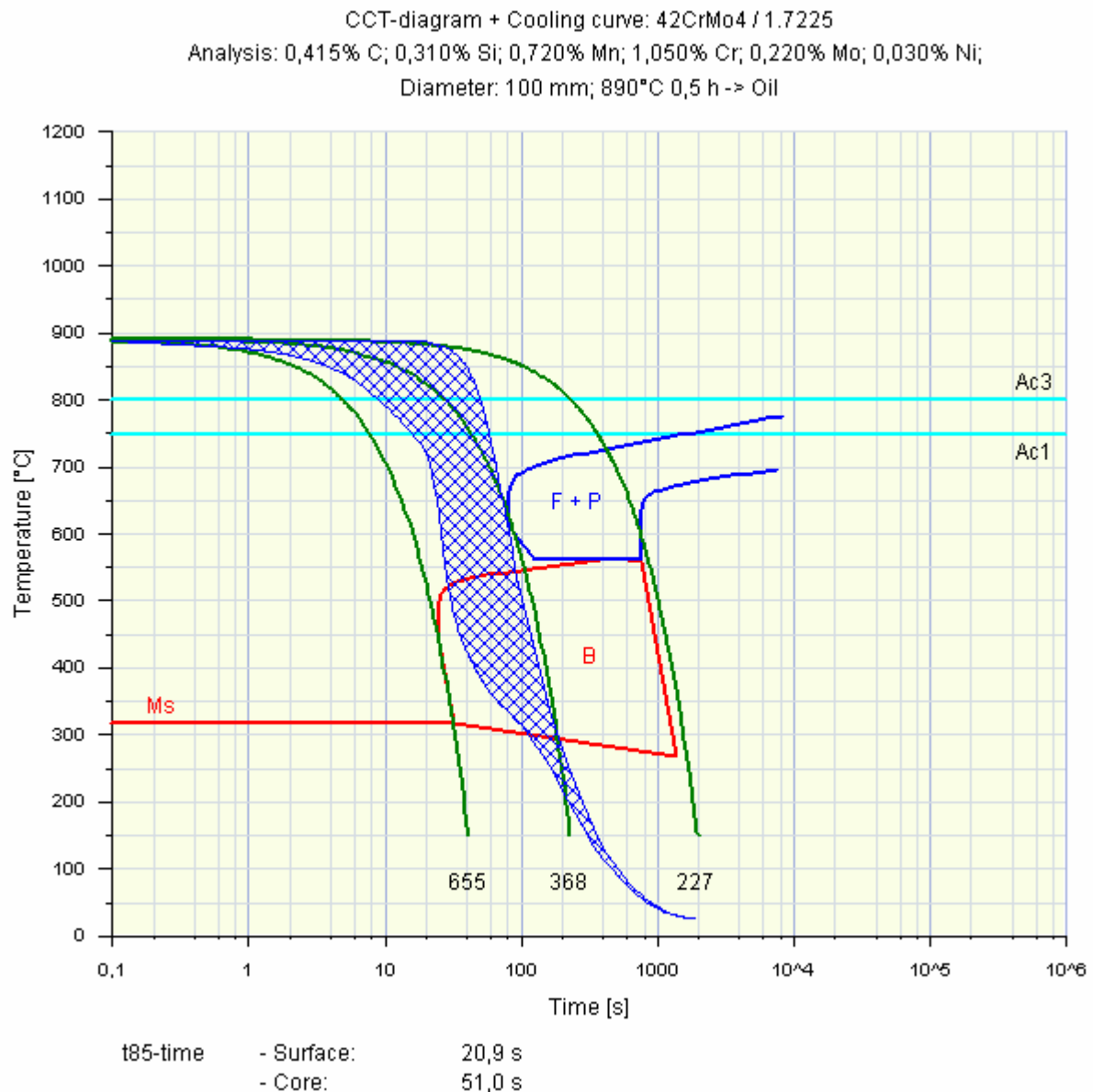
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Transformation temperatures



Transformation temperatures: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni; 0,005% P; 0,005% S 0,005% Cu
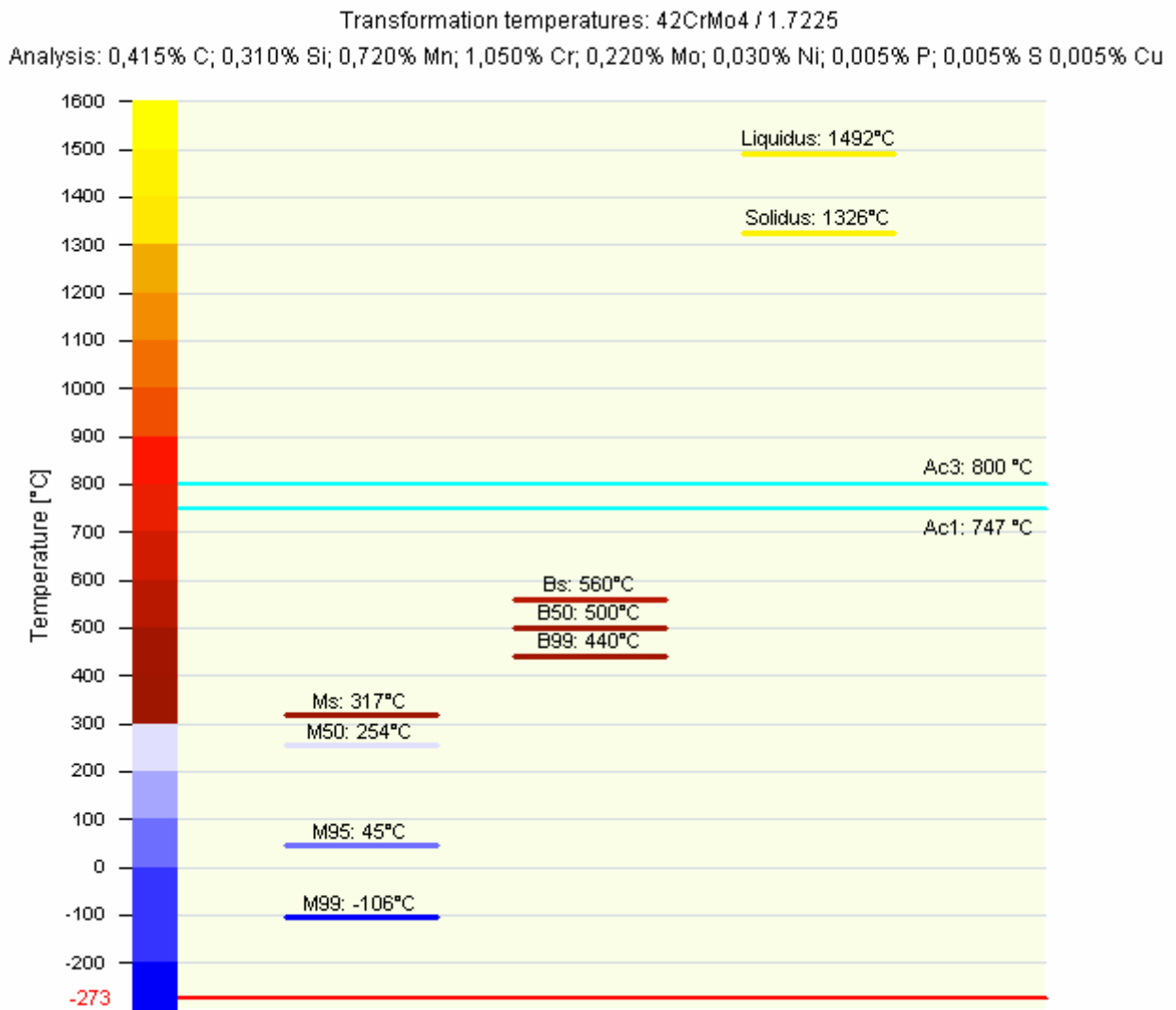
Before calculating the mechanical properties the program calculates the transformation temperatures depending on the chemical composition. Temperatures Ac1, Ac3, MS, M50, M95, M99, BS, B50 and B99 describe the structure transformation of steels to adjust an equilibrium or a desequilibrium.

If one of the elements S, P or Cu is filled the liquidus- and solidus-temperatures are calculated and displayed.

The related chemical composition is displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Structure diagram



Structure: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil

Based on the selected calculation the simulated amounts for martensite, bainite and ferrite/pearlite are displayed in a diagram as lines. Elements for drawing the lines are the amounts at surface, core and at the middle between.
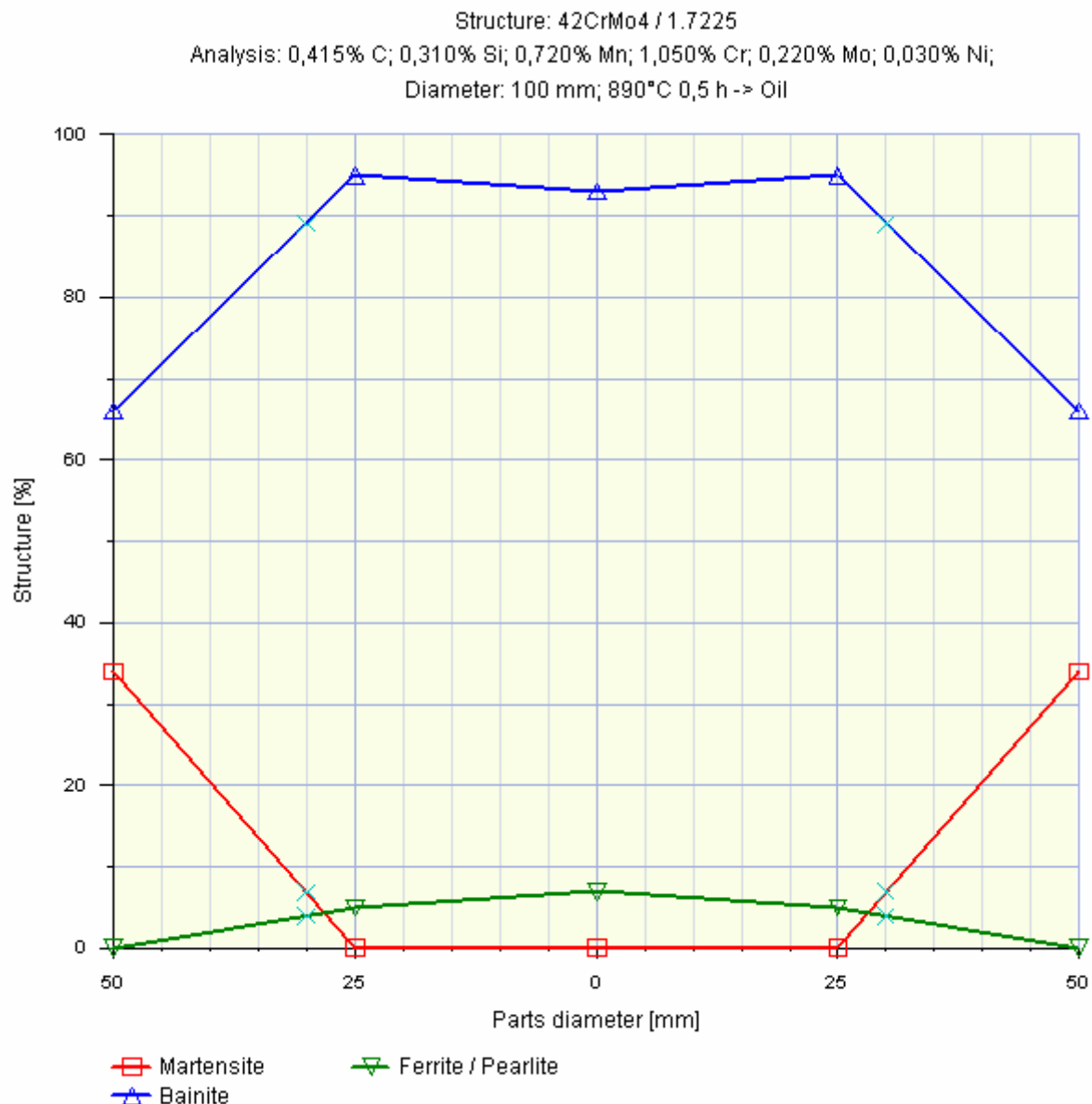
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Amount structure diagram



Structure allocation: 42CrMo4 / 1.7225

Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;

Diameter: 100 mm; 890°C 0,5 h -> Oil

Based on the selected calculation the simulated amounts for martensite, bainite and ferrite/pearlite are displayed in a diagram as added areas. Elements for drawing the areas are the amounts at surface, core and at the middle between.
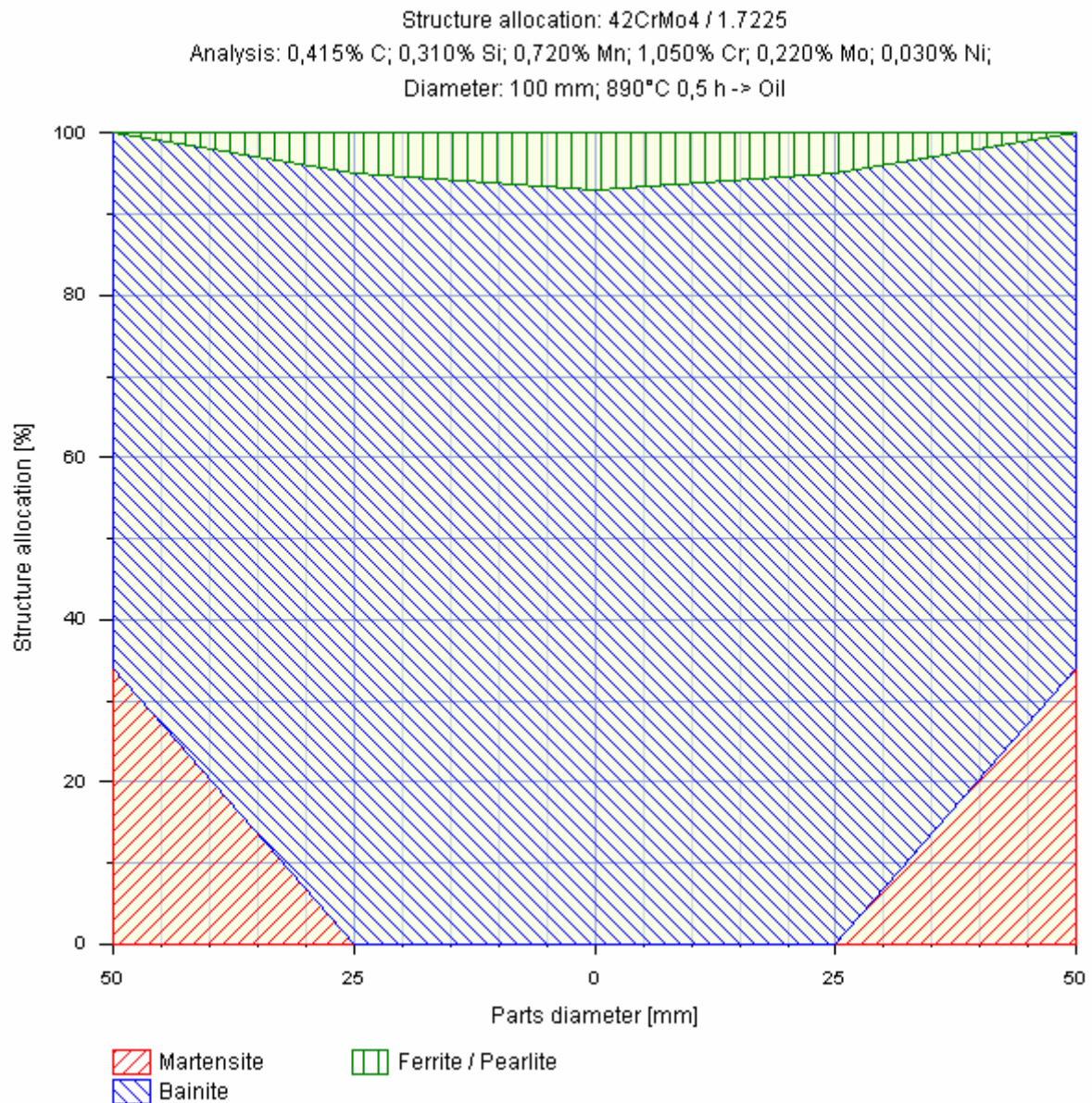
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

**Tempering diagram(1)**



Tempering diagram(1) describes the function of an as-tempered hardness depending on a specific tempering temperature for a material. This tempering diagram is always calculated depending on a round shape (20 mm) quenched in oil.
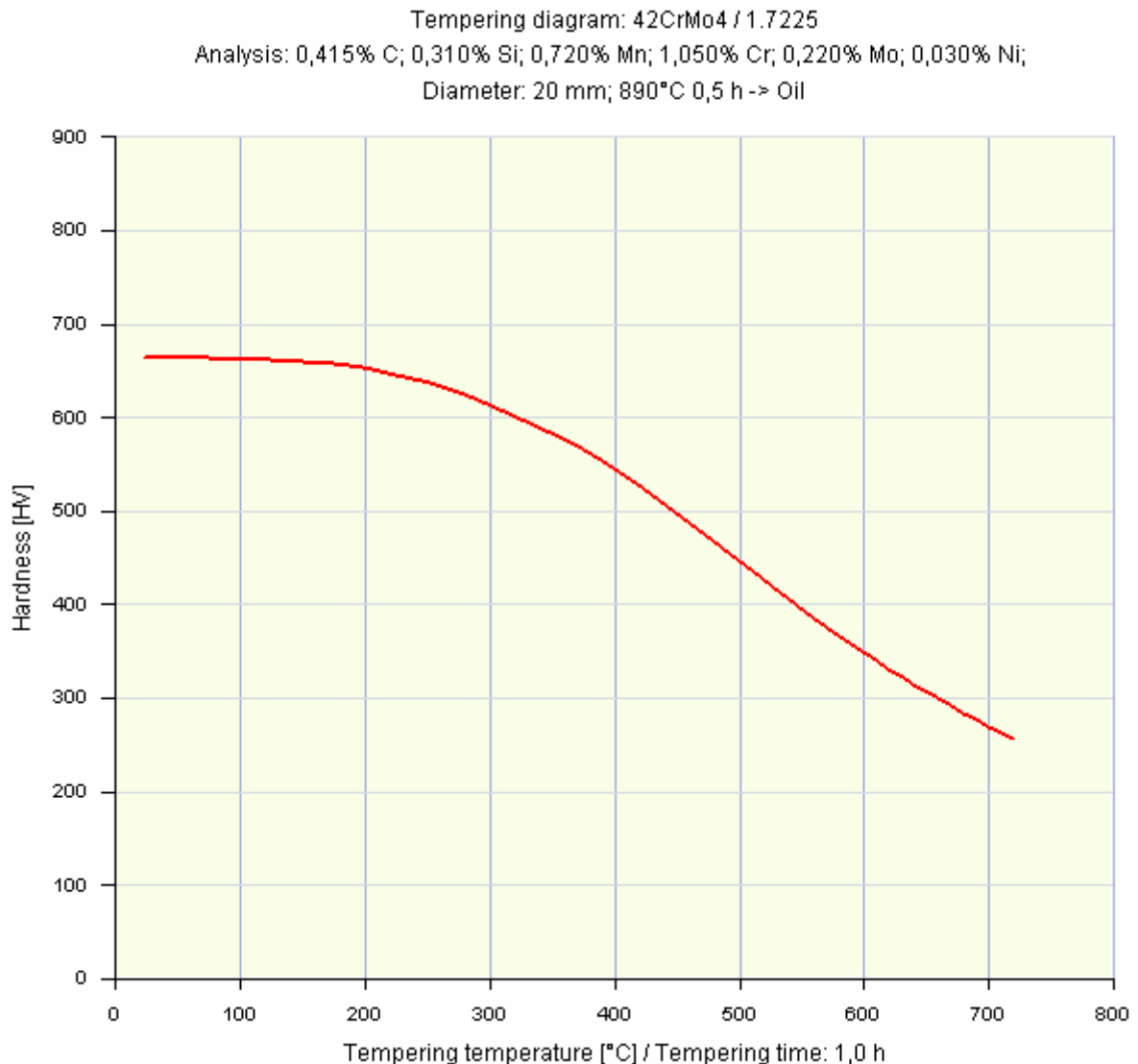
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

**Heat treatment**

The heat treatment includes …

- Heat treatment profile
- Temperature-time-diagram
- Temperature-time-diagram with profile
- Temperature difference
- Tempering diagram(2)

## Heat treatment profile

Plant profile: 42CrMo4 / 1.7225

Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;

Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h -> Air



—— Plant profile

The plant profile of the determined heat treatment cycle is displayed in a diagram as a line.

The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.
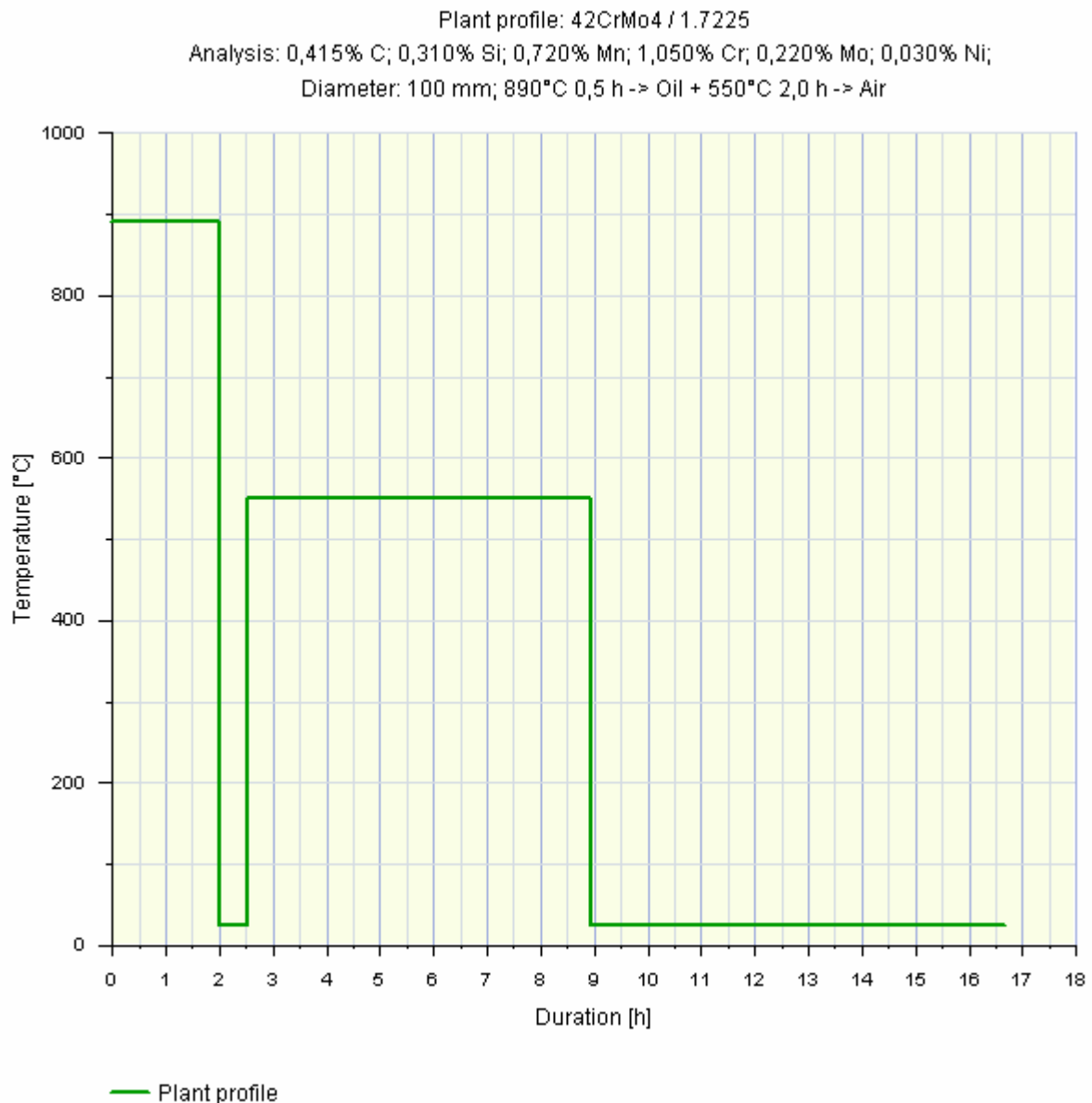
With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

**Temperature-time-diagram**



Temperature-time: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h -> Air

Based on the selected calculation the simulated temperatures in the part are displayed in a diagram as lines. Elements for drawing the lines are the surface and the core of the part.

The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Temperature-time-diagram with profile



Temperature-time + Plant profile: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h -> Air

Based on the selected calculation the simulated temperatures in the part are displayed in a diagram as lines. Elements for drawing the lines are the surface and the core of the part. The plant profile of the determined heat treatment cycle is displayed as an additional line in this diagram.
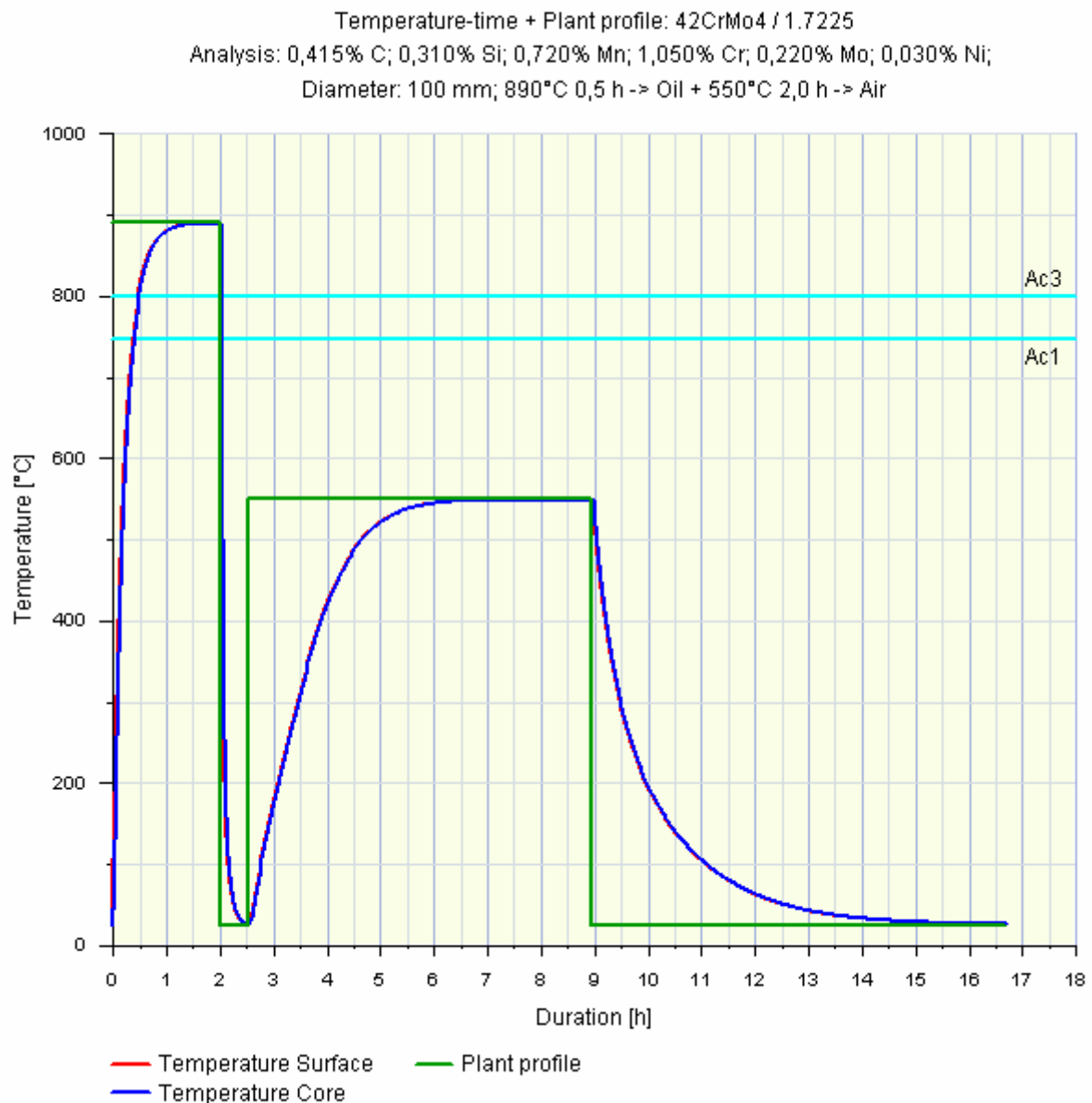
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

## Temperature difference



Temperature-time + Delta-T: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h -> Air

Based on the selected calculation the simulated temperatures in the part are displayed in a diagram as lines. Elements for drawing the lines are the surface and the core of the part. The temperature difference (Delta-T) between surface and core is displayed as an additional line in this diagram.
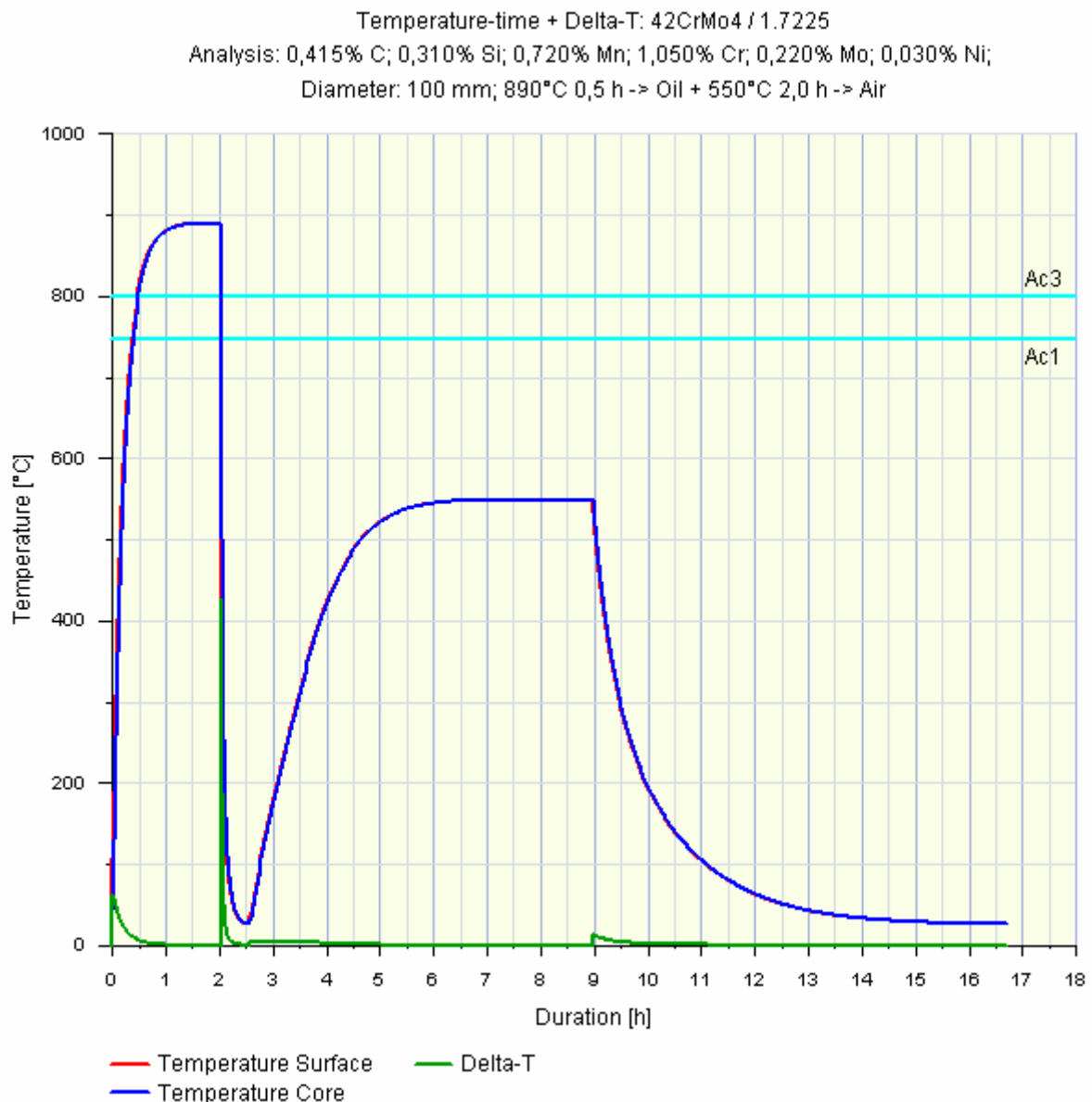
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

**Tempering diagram(2)**



Tempering diagram Surface: 42CrMo4 / 1.7225
Analysis: 0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil

Tempering diagram(2) describes the function of mechanical properties depending on a specific tempering temperature between 480°C and 700°C for a material. This tempering diagram always is based on the selected calculation.
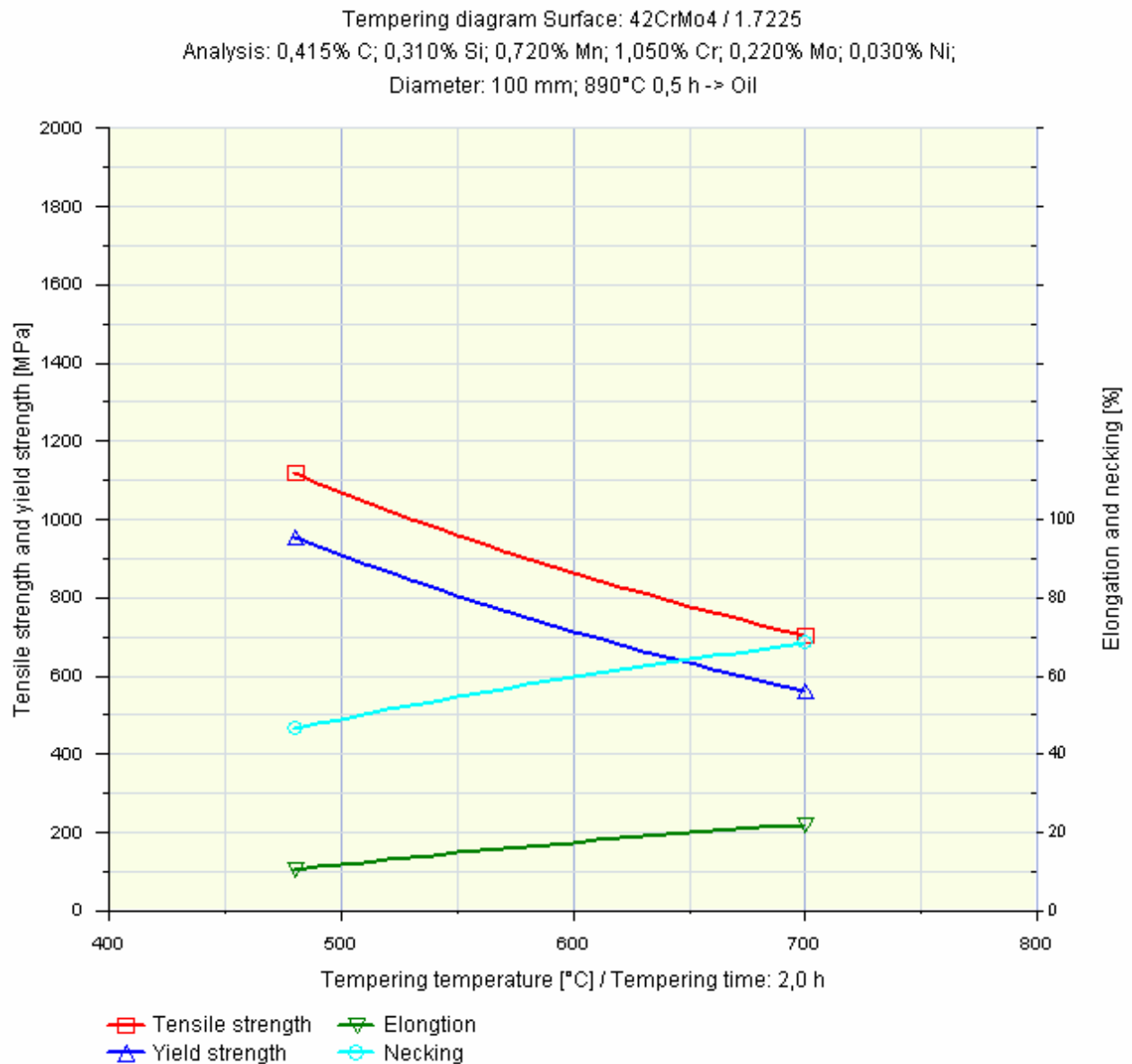
The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

**Optimizing**

Optimizing includes …

- Calculated tempering temperature

- Calculated alloy influence

## Calculated tempering temperature

This part of the program allows to calculate an optimized tempering temperature based on the component, its chemical composition, the hardening and quenching process before tempering, the tempering time and a mechanical property to be realized. In the following window all basic informations for the calculation are defined. After determing the mechanical property the value to be realized must be entered. Before the calculation starts for all necessary fields a precheck is done. So it is sure that only calculations can be started in which the data are proved and do not exceed the limitations of the mathematical model.

| Aim | | | | | | | | Aim | [Min] |
|---|---|---|---|---|---|---|---|---|---|
| Tensile strength [679 - 1119 MPa]: Surface | | | | | | | | 920 | 120 |

**Calculate**

**Analysis**
0,415% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;

**Part and treatment**
Round shape; Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h -> Air

**Optimized tempering**

| | Media | Alpha | Media temperature Start [°C] | End [°C] | [min] | Parts temperature End [°C] | [min] |
|---|---|---|---|---|---|---|---|
| 3. | Heating - Air | 0 | 550 | 550 | 0 | 550 | 120 |

**Structure / properties**

| | | Surface | Middle | Core | 1/5 ø |
|---|---|---|---|---|---|
| Martensite | % | 34 | 0 | 0 | 7 |
| Bainite | % | 66 | 95 | 93 | 89 |
| Ferrite / Pearlite | % | 0 | 5 | 7 | 4 |
| Hardness before tempering | HV | 466 | 355 | 345 | 377 |
| Hardness after tempering | HV | 315 | 285 | 283 | 291 |
| Tensile strength | MPa | 960 | 866 | 862 | 885 |
| Yield strength | MPa | 806 | 692 | 685 | 715 |
| Bending fatigue strength | MPa | 517 | 471 | 468 | 480 |
| Elongtion | % | 15 | 16 | 16 | 16 |
| Necking | % | 55 | 56 | 56 | 56 |

It must be remarked that the tempering temperature of the selected calculation will be calculated new. The program more often repeats the calculation for tempering temperatures between 25°C and (Ac1-20°C) and compares the results with the aim value determined above. This happens until the aim value reached in some small tolerances. The last calculated temperature is displayed as the optimized tempering temperature.

## Calculated alloy influence

This program part allows to calculate the influence of one alloying element based on the component, its chemical composition, the hardening and quenching process and if deter-mined the tempering process. In the following window all basic informations for the calcu-lation are defined. After determing the alloying element the range and the step value must be entered. Before the calculation starts for all necessary fields a precheck is done. So it is sure that only calculations can be started in which the data are proved and do not exceed the limitations of the mathematical model.

| Specify element | | from | upto | Step |
|---|---|---|---|---|
| C [0,05 - 0,60 %] | ▼ | 0,3 | 0,55 | 0,01 |

Calculate

**Analysis**
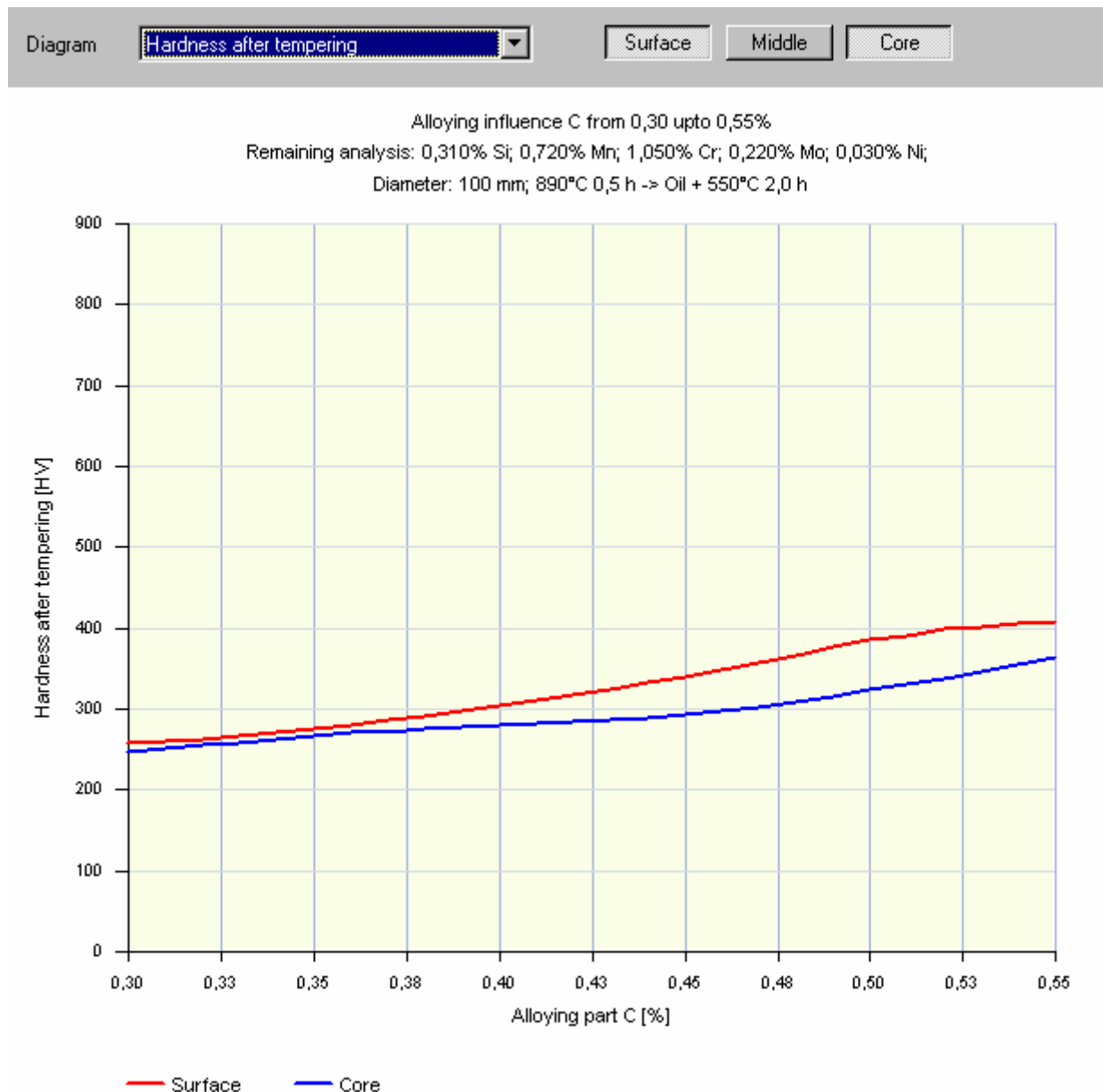0,300% C; 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo;

**Part and treatment**
Round shape; Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h -> Air

| Structure / properties | | Surface | Middle | Core | 1/5 ø |
|---|---|---|---|---|---|
| Martensite | % | 0 | 0 | 0 | 0 |
| Bainite | % | 93 | 82 | 73 | 84 |
| Ferrite / Pearlite | % | 7 | 18 | 27 | 16 |
| Hardness before tempering | HV | 319 | 295 | 282 | 300 |
| Hardness after tempering | HV | 259 | 253 | 248 | 254 |
| Tensile strength | MPa | 790 | 777 | 765 | 780 |
| Yield strength | MPa | 619 | 595 | 574 | 600 |
| Bending fatigue strength | MPa | 438 | 428 | 419 | 430 |
| Elongtion | % | 18 | 19 | 19 | 19 |
| Necking | % | 60 | 59 | 58 | 59 |

| C | Martensite Surf | Bainite Surfa | Ferrite / Pearlit | Martensite Mid | Bainite Mid | Ferrite / Pearlil | Martensite C |
|---|---|---|---|---|---|---|---|
| 0,300 | 0 | 93 | 7 | 0 | 82 | 18 | 0 |
| 0,310 | 0 | 93 | 7 | 0 | 85 | 15 | 0 |
| 0,320 | 0 | 94 | 6 | 0 | 87 | 13 | 0 |
| 0,330 | 0 | 94 | 6 | 0 | 90 | 10 | 0 |
| 0,340 | 1 | 97 | 2 | 0 | 91 | 9 | 0 |
| 0,350 | 4 | 96 | 0 | 0 | 91 | 9 | 0 |

After the calculation the results are displayed in a browser below the input window. It is possible to display all results in diagrams. The selection of kind of diagram can be done in the selection list above the diagram. The values to be shown can be selected by clicking the buttons for surface, core and the middle between. As a standard the values for surface and core are displayed.

Diagram [Hardness after tempering ▼]   [Surface]  [Middle]  [Core]

Alloying influence C from 0,30 upto 0,55%
Remaining analysis: 0,310% Si; 0,720% Mn; 1,050% Cr; 0,220% Mo; 0,030% Ni;
Diameter: 100 mm; 890°C 0,5 h -> Oil + 550°C 2,0 h

—— Surface   —— Core

The related geometry, the heat treatment cycle and the chemical composition are displayed above the diagram.

By clicking the left mouse button in the diagram all coordinates can be displayed with their x- and y-values. They are shown in the upper right corner of the diagram. By clicking the right mouse button these coordinates can be deleted again.

With menu "View/Navigation bar" or function key "F3" the navigation bar (treeview) can be toggled on and off.

With keys "Ctrl + left mouse button" at the same time all diagrams can be copied into the windows clipboard. So all diagrams can be pasted into other applications.

# Extras

## Options
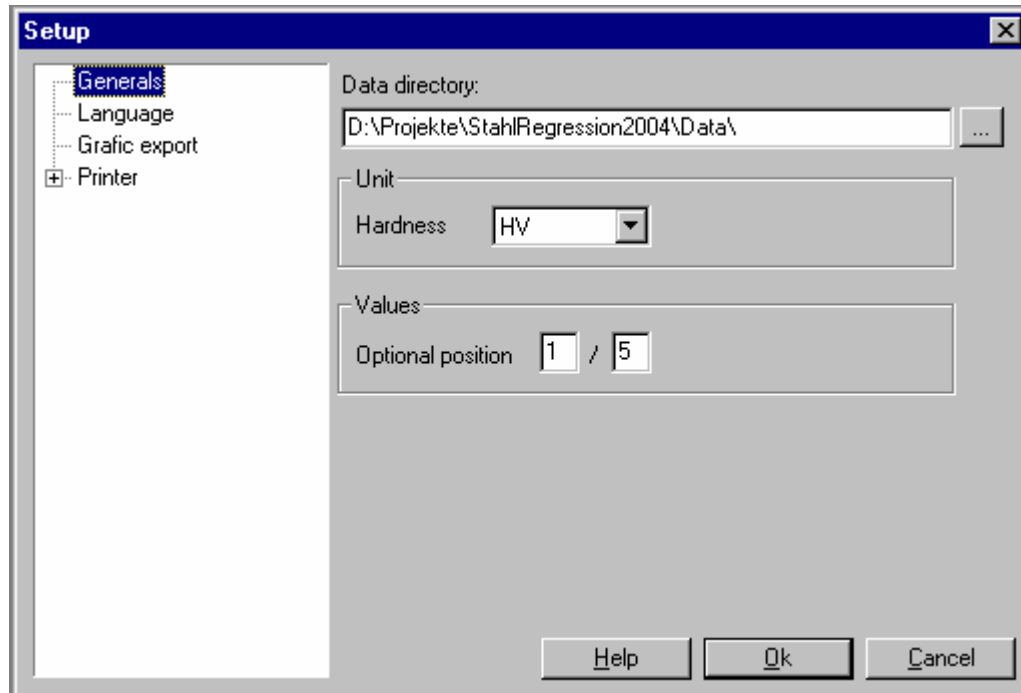


In this window the data path and the physical unit for displaying the hardness can be de-termined. With the optional position the user can determine one auxiliary position in the part to be calculated in addition to surface, core and the middle between.

Also the user can set the language. Normally german language is set.

At least the user can set up two printers for text prints and for graphic prints.

In case that after determining the data path an error message occurs that an index file is corrupted or missing, the window for reorganization appears afterwards. The button OK must be pressed to start the reorganisation. Thereafter the program is ready for use.

**Reorganization**

Reorganizazion of data can only be done if all program windows are closed and no other user works with this program. Normally all data should be reorganized:
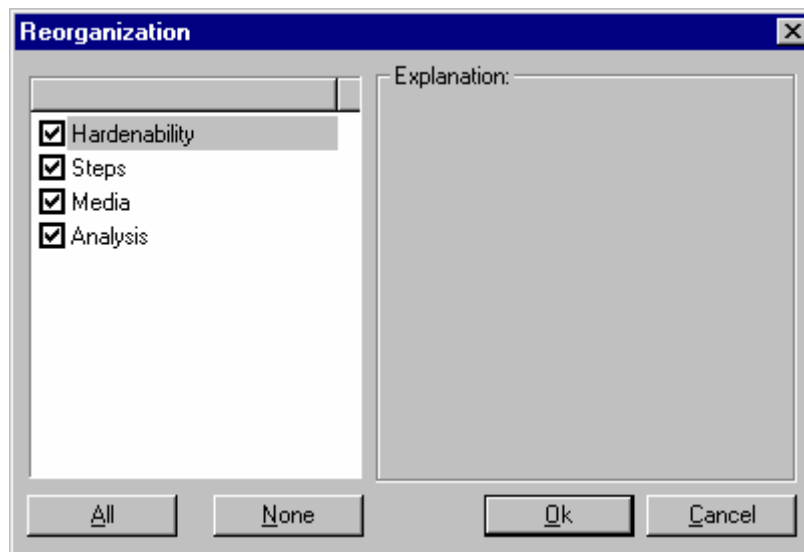


After clicking the button "Ok" the reorganization starts. This can last some time. After the reorganization the program is ready for full use.

# Contact

**Contact**

If there are any questions while using the program there is the possibility to call LOI, Essen, Germany from  8:30 to 16:30 MEZ.


www.loi.de


info@loi-italimpianti.de


Important:

An aimed question reduces the answering times. Therefore the user should have the following informations before calling the hotline:

What program version is used? This information is available with menu item "Help - about".

The hotline needs a accurate description of the problem. For example: "When I choose menu item 'X' follwing error message 'Y' appears."

What kind of windows is used and what software is also installed on the computer?

What components are also installed (printers, scanners, …)?