

# *APM Shaft*

---

User's Guide

# APM Shaft

The system for shafts and axles calculation and design

Version 9.0

---

## User's Guide

Research and Software Development Center APM Ltd., Korolev-Center, box 58,  
Moscow Region, Russia, 141070

Copyright © 1990—2006 by Research and Software Development Center APM Ltd. All rights reserved. All APM products are trademarks and registered trademarks of APM Ltd. Other brand and product names are trademarks and registered trademarks of their respective holders.

Printed in Russia.

## Introduction

---

### **APM Shaft — what is it?**

APM Shaft is a system for shaft and axle calculation and design, developed by the Research and Software Development Center APM Ltd. (Moscow).

The following parameters can be calculated in the APM Shaft

- Reactions in the supports
- Moments of bending and angles of bending
- Moments of torsion and angles of torsion
- Deformations
- Stresses
- Fatigue strength safety factor
- Axial forces
- Natural frequencies and shapes

The system includes a specialized graphical shaft editor that allows you in a few minutes to draw shaft construction along with loads applied to it.

### **Hardware and software requirements**

APM Shaft runs on the IBM PC family of computers (including all true IBM compatibles) Pentium III processors. APM Shaft is intended to run under Microsoft Windows 2000 or XP.

### **What's in this manual**

**Introduction** (this section) tells you what **APM Shaft** is in general. You will know the requirements to hardware and system software.

**Chapter 1, Problems, initial data and results** contains description of the problems that can be solved with **APM Shaft**.

**Chapter 2, Shaft editor** tells you about specialized shaft editor — a convenient and powerful tool that allows you to enter all the data required to calculate shaft in a “visual way.”

**Chapter 3, Command reference** contains complete description of all commands of the main menu and popup menus.

### **Typefaces used in this book**

To facilitate reading and avoid misunderstanding we use a set of typefaces. Their uses are as follows.

<code>a:\setup</code>	This typeface represents text as it appears or anything you must type (for example, <code>a:\setup</code> to start installation program).
<code>SETUP.EXE</code>	We use all capital letters for the names of files and keys.
<b>Help</b>	APM Shaft command names are shown in boldface.
<i>Results</i>	Italics is used for the names of dialog boxes and controls

## **How to contact APM**

Phone +7(495) 585-06-11, 514-84-19.

Address:

**Research and Software Development Center APM LTD  
Korolev-Center, box 58,  
Moscow Region  
141070 Russia**

E-mail: [com@apmwm.com](mailto:com@apmwm.com)

## Chapter 1 Problems, initial data and results

---

### Shafts: purpose and classification

**S**hafts and axles are used to install rotating machine elements such as gear wheels, pulleys, sprockets, etc. *Shaft* is intended both for supporting machine elements mounted on it and for torque transmitting. During operation, shaft is subject to the bending and torsion and sometimes to the compression and tension. *Axle* is intended only for supporting machine elements. In contrast to shaft axle does not transmit torque and therefore is not subject to the torsion. The axles can be either immovable or can be rotated together with machine elements mounted on them.

### Calculation of the shafts

#### Criterion used for shaft calculation

During operation, shafts are subject to substantial loads, and therefore in order to determine optimum dimensions of shaft, it is necessary to calculate the following parameters:

- static strength
- fatigue strength
- stiffness in bending and torsion stiffness

At high rotation speed, it is required to determine natural frequencies of shaft in order to prevent running into resonance zones.

Long shafts are checked for stability.

### Static strength calculation

This calculation has a checking nature. Using it one can calculate safety ratios for the shaft of given construction. As a rule, construction and dimensions of a shaft are determined by its purpose. The calculation must confirm or reject the construction developed by designer depending on the static strength. It should be noted, that static strength is not the only criteria for shaft construction correctness. Final conclusion can be made only after checking all the criterion mentioned above.

For static strength calculation shaft is considered as a round beam of variable cross-section. Shafts are produced from the steel, mechanical properties of which determine safety ratio values for the given loading. Therefore, the purpose of shaft calculation can be formulated as searching for such values of mechanical properties of shaft material that provide predefined safety ratio values under given loading.

If the stresses have equal values in each cross-section of the shaft such shaft is called uniform-strength shaft. For several reasons, it practically impossible to design uniform-strength shaft, however the nearer real stresses to the stresses that should take place for uniform-strength shaft, the better shaft material will be used.

When calculating static strength along with shaft dimensions, loads applied to the shaft should be entered, including

- concentrated and distributed radial forces,
- axial forces,
- bending moments,
- moments of torsion.

It is necessary also to specify shaft fixing conditions by entering a finite number of bases.

When you enter moments of torsion you should check for torsion balance. If torsions are not balanced the system will ignore the values of torsion moment you have entered.

The number of bases in APM Shaft should not exceed 50.

Static strength calculation includes determination of bending moments and moments of torsion in the selected sections of the shaft, as well as calculation of bending and torsion stresses. The strength of the shaft is estimated by equivalent stress value that is calculated based on the maximum tangential stresses hypothesis. In the case of statically indeterminate shaft reactions in the bases are calculated with the method of forces. Calculated values of moment of bending are displayed as epures in two mutually orthogonal planes. Moments of torsion and equivalent stresses are displayed as graphs. Static strength is considered sufficient if safety ratio is 1.3—1.5 or more. Safety ratio is the ratio of yield point to equivalent stress in the most loaded part of the shaft. As additional parameters, reactions in the bases are calculated; they are required for calculation of parts mounted on the shaft.

### **Fatigue strength calculation**

Rotation of the shaft creates the stresses variable in time. If external load applied to the shaft is variable, the irregularity of stresses increases even more. Variable nature of stresses leads to formation of fatigue cracks that can be the cause of destruction. Destruction starts in the most stressed part of the shaft; the local stresses are of great importance for its origin and development. These stresses arise in the grooves, fillets, keys, splines, threaded zones, etc.

Fatigue strength calculation is based on the nominal torsion and bending stresses, accounting for local stresses in the considered zone of the shaft. Local stresses are considered by means of stress concentration factors; values of these factors depend on type of concentrator.

Results of fatigue stress calculation are displayed as a graph that shows how safety ratio for fatigue strength is changing along the shaft length. Safety ratio is calculated for long-term strength. Since the accuracy of this factor is substantially lower than that of static strength, minimum allowable value should not be lower than 2.5. APM Shaft includes facility that handles variable nature of external loads; it reduces variable loading to equivalent constant loading.

### **Calculation of stiffness**

In some cases the stiffness becomes an important criteria that determines the suitability of shaft construction. Remember that stiffness is the load that cause deformation equal 1 (in the used system of measurements).

Stiffness calculation in the APM Shaft includes determination of deformations, caused by the load applied. To calculate the deformation, the method of Moor integral is used. According to the nature of load, the stiffness is divided into rigidity in bending and torsion rigidity; in APM Shaft you can calculate both of these types. The results of calculation are displayed as a graph that shows how stiffness changes along the shaft length. Sometimes it is necessary to determine angles of torsion for different cross-sections of the shaft and to get torsion parameters that are calculated by means of differentiation of deformation curve; APM Shaft provides you with such calculations. Stiffness condition is considered fulfilled if actual deformations and slopes of cross-sections do not exceed allowed values. The latter depend on the purpose of the designed equipment and required accuracy.

## Chapter 2 Shaft editor

---

**S**haft editor included in the APM Shaft is the specialized graphics editor intended to enter shaft geometry. Shaft editor provides user with convenient tools for:

- specifying shaft geometry
- entering loads applied to the shaft
- placing the bases

Main difference between APM Shaft and traditional CAD systems consists in the set of primitives they operate with. The set of primitives in APM Shaft consists of the main features of shaft construction (cylinder and cone sections, fillets, chamfers, grooves, openings, threads, keys и splines) and of symbols for the loads that can act upon the shaft and bases the shaft is placed on. Such set of primitives substantially simplifies entering of geometry and other data required for calculations.

### Editor layout

Main components of editor are editor window, rulers, toolbar and status line.

### Editor window

Editor window is the main part of shaft editor. It is used to draw, edit and display shaft.

### Rulers

Shaft editor includes two rulers—horizontal and vertical. Rulers have scales that depend on current scale factor and shaft part shown in editor window at the moment.

### Status line

Status line is used to display current dimensions, coordinates, etc. during shaft drawing. The number of displayed parameters depends on the element being drawn. For example, when you draw cylinder section, current values of cylinder length and diameter are shown in the status line.

### Toolbar

Toolbar is a set of bitmap buttons that call most frequently used editor commands. To carry out a command just click on the appropriate button. Commands of toolbar buttons are described in Chapter 3 *Command reference*.

### Scrolling and scroll bars

The shaft drawn by user can exceed the editor window extents. The scroll bars allow to move shaft relative to the editor's window.

### Editor window enlarging

User can enlarge editor window area by hiding rulers, toolbar and status line. To do this use commands **Rulers**, **Toolbar** and **Status Line** in the popup menu **View**. At any time each of these elements can be shown again.

### Scaling

To change drawing scale use **Settings | Scale** command. In the dialog box shown in fig. 3.6 you can either enter required scale in the *Scale* edit box or select one of standard scales (1 : 2, 1 : 5, 1 : 10, etc.).



## Palette editor

Palette is a set of colors used to draw shaft elements, loads and bases, as well as editor window background color and grid color. User is provided with four predefined palettes—"gray", "white", "black" and "printer". To select palette use **Settings | Palette** command.

## Auxiliary grid

To provide better visual control during shaft drawing auxiliary grid can be shown on editor window. Use **Settings | Grid** command to select grid step and line type.

## Cursor step

When working with shaft editor user can adjust accuracy of coordinates and dimensions entering. By default accuracy equal to 1 mm is used. That is all dimensions of shaft elements and all coordinates when entered interactively with mouse will be rounded to millimeters. You can change accuracy using **Settings | Cursor Step** command.

## Basic principles of editor

### Mode selection

To specify shaft construction user should enter its elements; to make calculation loads and bases should be specified. **To draw or edit any of shaft element it is necessary to switch editor into mode that intended for drawing objects of this type.** For this purpose you should select corresponding toolbar button or menu command. Current drawing mode is indicated by form of mouse cursor. It corresponds to the objects the graphic editor deals with at the moment.

### Shaft drawing

The primitives of shaft editor can be divided on "point" and "extended".

"Point" elements are objects to place which you have to specify either one axial coordinate (for example distributed forces, bases) or part (for example, to place fillet it's necessary to point at zone of cylinders contact, to place chamfer—cylinder end). To enter elements of this type move cursor to desired point or zone and click left button of the mouse. As a result, dialog window for entering element parameters (for instance, force value or fillet radius) will be invoked.

"Extended" objects are cylindrical and conic segments, threads, opening, keys and splines, distributed forces. To enter these elements, it's necessary to specify the dimensions of corresponding object (for example, start and end points of cylindrical section and its diameter). Sequence of actions is as follows. First place cursor at the point where element begins and press left button of the mouse. Then, holding the button, move cursor to the point where element ends and release button. While cursor is moved with depressed mouse button the current element size is drawn and current values of main parameters are shown in the status line. After releasing of the mouse button, the dialog window can be displayed to specify element parameters more precisely.

Shaft elements may be divided also on "primary" and "secondary". Primary elements are cylinder and cone sections of the shaft. All other elements are secondary—they can be entered only after you have specified the primary element and only in the boundaries of shaft (i.e., for example you cannot specify the load before you draw the shaft, etc.).

We recommend the following sequence of shaft drawing

- to draw cylinder and cone sections of the shaft
- to enter transitional elements (chamfers, fillets, grooves)
- to specify openings, threaded zones, keys and splines
- to define loads applied to the shaft and bases supporting the shaft

### Editing

Editing includes changing dimensions and parameters of shaft elements as well as their deletion. **To edit shaft you should switch editor into drawing of those elements that**

**you want to edit.** To edit object first you should select it. To do so, place cursor on object and click **right** button of the mouse. (You should click near enough to the object that the program could determine which object you want to edit; it is unnecessary to place cursor directly on the object) Dialog box appears on the screen that contains object's parameters and *Delete* button. You can enter new values of parameters or delete the object.

## Diagnostics

When you work with shaft editor the system tries to check your actions. For example, it does not allow you to apply loads or place bases beyond the shaft's extents; you could not draw the hole with diameter greater than that of the shaft, etc. However, it is difficult to foresee all possible erroneous actions, so you should check the shaft you are drawing.

You should be attentive during shaft editing. We illustrate this by an example. Suppose you have cylinder section which length is 100mm. It includes a threaded zone with length 90mm. Then you decide to decrease section length to 50mm but didn't decrease the threaded zone length. As a result, threaded zone will indent into the next section (that can have another diameter) or even go out of shaft altogether.

## Shaft elements

Using shaft editor you can enter the following shaft elements:

- cylinder sections
- cone sections
- chamfers
- fillets
- grooves
- axial openings
- threaded zones
- keys
- splines
- perpendicular openings

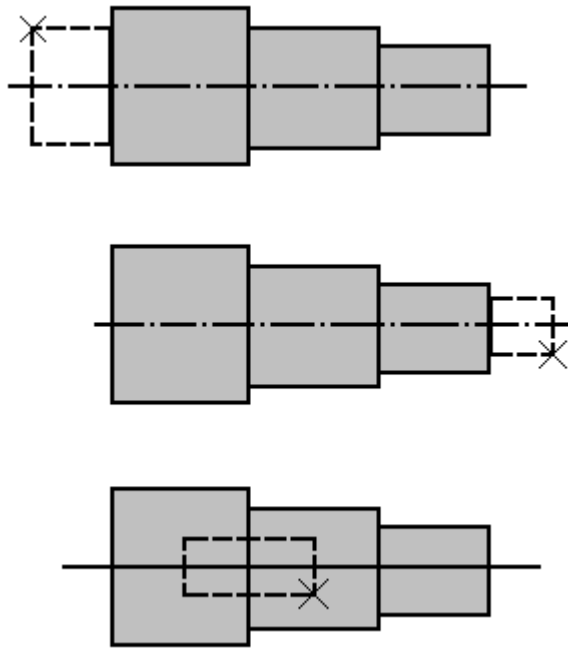
## Cylinder section drawing

To draw cylinder section select **Draw | Cylinder** menu command or **Cylinder** button in the toolbar.

Cylinder section can be drawn in three ways (Fig.2.1):

- adding section to the left of existing shaft
- adding section to the right of existing shaft
- inserting section between two existing sections

Cylinder drawing mode is determined by initial position of cursor. If the nearest to the point where you have pressed the mouse's button is the left edge of the shaft, new section will be added to the left of the shaft (Fig.2.1 a); if the right edge of the shaft is the nearest then new section will be added to the right of the shaft (Fig.2.1 b). In other cases the new section will be inserted between sections (Fig.2.1 c).



*Fig. 2.1 Adding of the new sections to the shaft.: a)to the left of the shaft, b)to the right of the shaft, c)to the middle of the shaft. The crosshair shows initial cursor position. Horizontal movement of cursor changes the length of the section, vertical—its radius.*

To add new section to the left edge of the shaft place cursor to the left of existing shaft and press mouse's left button and hold it. Then moving the cursor, specify the section length and diameter. Current values of these parameters are shown in the status line. New section is drawing with the color different from the color of the shaft. When you release mouse button new section will be redrawn with shaft color.

If you place cursor on the first section (but closer to its left end) the new section will be also added on the left. In this case shaft will be moved to the right, and the left edge will remain at the same place.

In the same way new section is added to the right edge of the shaft.

If you want to add new section inside the shaft, place the cursor on boundary of the sections between which you want to insert the new one. Then press left button and specify the size of new section.

## **Editing and deletion of cylinder and cone sections**

To edit or delete some shaft element it's necessary to select it. For this purpose set drawing mode of objects of this kinds (with the aid of menu command or toolbar button). For selection of demanded element move cursor to this one and click right mouse button. As a result dialog window is displayed. This dialog box contains edit controls filled with current values of edit element parameters and button for object deleting as well.

The common dialog window is used for cylinder and cone section editing (fig. 2.2). It contains edit controls for entering section length and section radiuses on left and right edges. So you may transform cylinder section to cone one and vice versa.

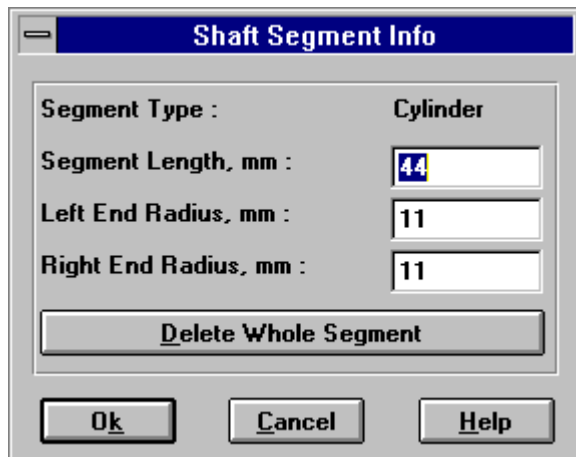


Fig.2.2 Dialog box for editing the shaft section parameters

## Cone section drawing

Cone section can be drawn in three ways (Fig.2.3):

- by start and end radii
- by start radius and conicity
- by start radius and angle of cone line

To set drawing way open **Draw | Cone** popup menu and select one of three commands **By Two Radii**, **By Conicity** or **By Angle**. Having selected two last commands you should enter conicity value and cone angle. For this purpose use **Draw | Cone | Set Conicity** or **Draw | Cone | Set Angle** commands.

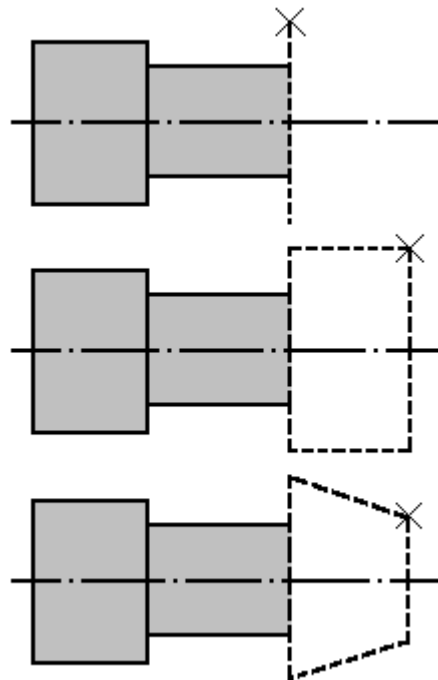


Fig.2.3 Sequence of cone drawing by start and end radii. a) start radius specifying; b) setting the cone section length; c) setting the end radius. Cursor position is shown by cross..

Cone drawing is very much like cylinder drawing. Suppose, you want to add cone section by its radii to the right shaft end (fig.2.3). Place cursor to the right of the shaft and press left button. Then holding the button set cursor on right shaft end and move it up or down

till you have the required left cone radius (this value is displayed in the status line) (fig.2.3a). After that, move cursor in horizontal direction to set desired section length (fig.2.3b) and finally, move it in vertical direction to set right cone radius (fig.2.3c). When you get the required form of the cone, release the mouse button. If you want to set the cone parameters more precisely click right button on it. As a result, dialog window for cone parameter editing will be displayed on the screen.

If you insert cone by angle or conicity then when you have specified start radius, a “rubber” cone is immediately drawn with defined angle (or conicity), so you have to enter one angle and the second one is set automatically. In this case two variants are available.

## Fillets

Fillet is a transitional element intended to decrease stress concentration in the place of contact of two shaft sections that have different diameters (fig. 2.4).

To draw fillet use **Draw | Fillet** menu command or *Fillet* toolbar button. Place cursor where you want to make fillet and click the left button. Dialog box will be displayed on the screen where you have to enter fillet radius.

**Editing and deleting.** Move cursor to fillet you want to edit (delete) and click the right button. The dialog box will be invoked where you can edit fillet radius or delete fillet.

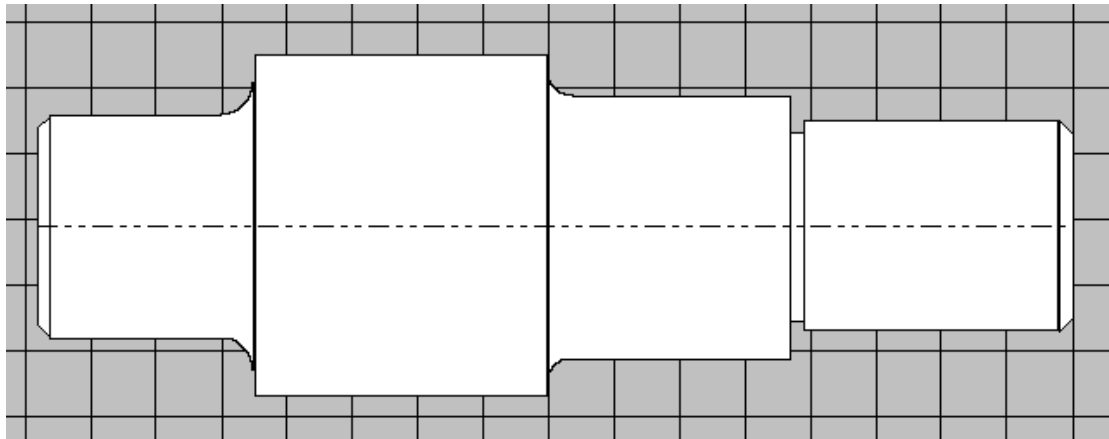


Fig. 2.4. APM Shaft Editor. Shaft fragment with chamfers, fillets and groove.

## Chamfers

Chamfer is a small cone zone at the edge of cylinder section of the shaft (fig. 2.4).

To draw chamfer select **Draw | Chamfer** command in menu or click **Chamfer** button in the toolbar. Place cursor on section edge where you want to make chamfer and click the left button. Dialog box will be displayed where you have to enter chamfer width and the angle between chamfer profile line and shaft axis. Enter data or use default values.

To edit or delete chamfer use the right button of the mouse. In the dialog box enter new values for chamfer parameters or select *Delete Chamfer* button.

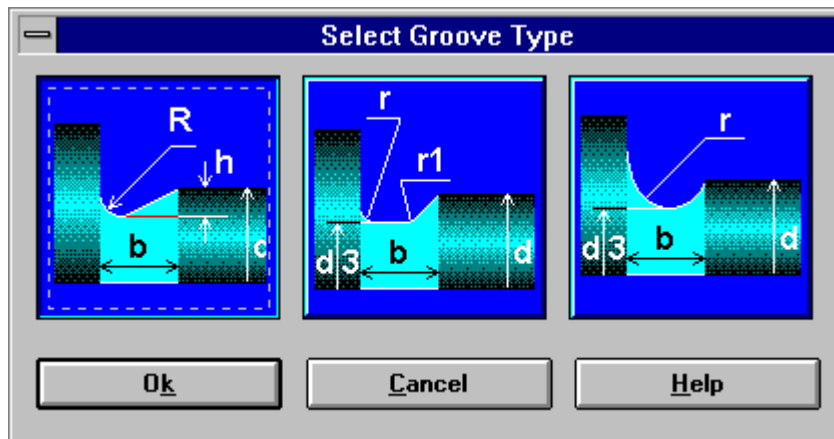


Fig. 2.5 Dialog box for groove type selection.

## Grooves

Shaft editor allows to specify grooves of three types (fig. 2.5). To draw groove select **Draw | Groove** command in menu or click on **Groove** button in the toolbar. Then place cursor where you want to make groove and click the left button. Dialog box will be invoked on the screen. In this dialog box you should select type of groove (fig 2.5). When you do it next dialog box will be displayed (fig. 2.6), where you can enter groove dimensions. By default, standard dimensions are used that depend on shaft diameter.

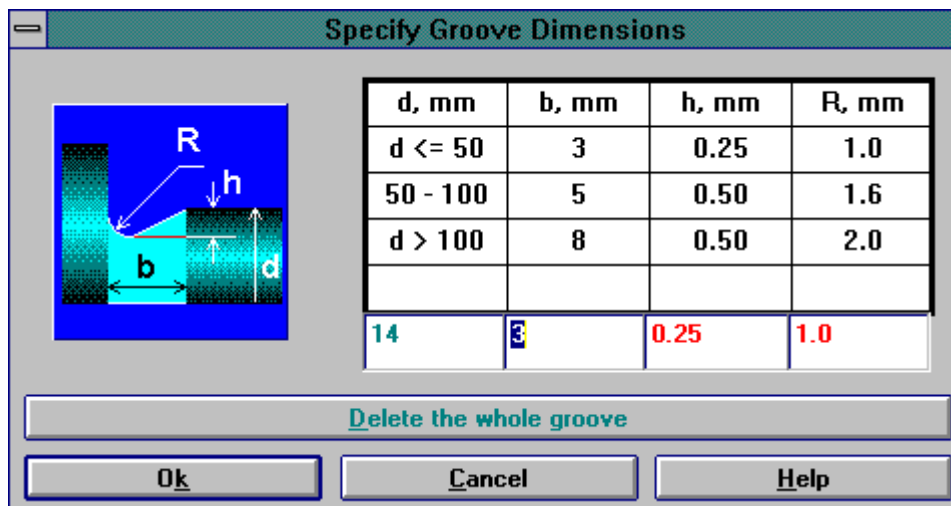


Fig. 2.6 Dialog box for groove parameters setting.

## Keys

Key joints are used to transmit torque between the shaft and the element mounted on it (such as hubs of gear wheels). Key is a steel bar inserted in the slot of the shaft and the element mounted on it. In the APM Shaft you can draw keys of four types—rounded on the left and right edges, rounded on the both edges and rectangular.

To draw key, you should select key type using popup menu **Draw | Key**. Then place cursor in the point that corresponds to either left or right edge of the key and press the left button. Holding the button, move cursor to the another boundary of key (when you move the cursor, a rectangle showing dimensions of the key is displayed) and then release the button. Dialog box will be displayed where you can enter more accurate parameters of the key. You should keep in mind that the key rounded on left edge always starts on the right end of a shaft section, whereas that rounded on the right edge starts on the left end.

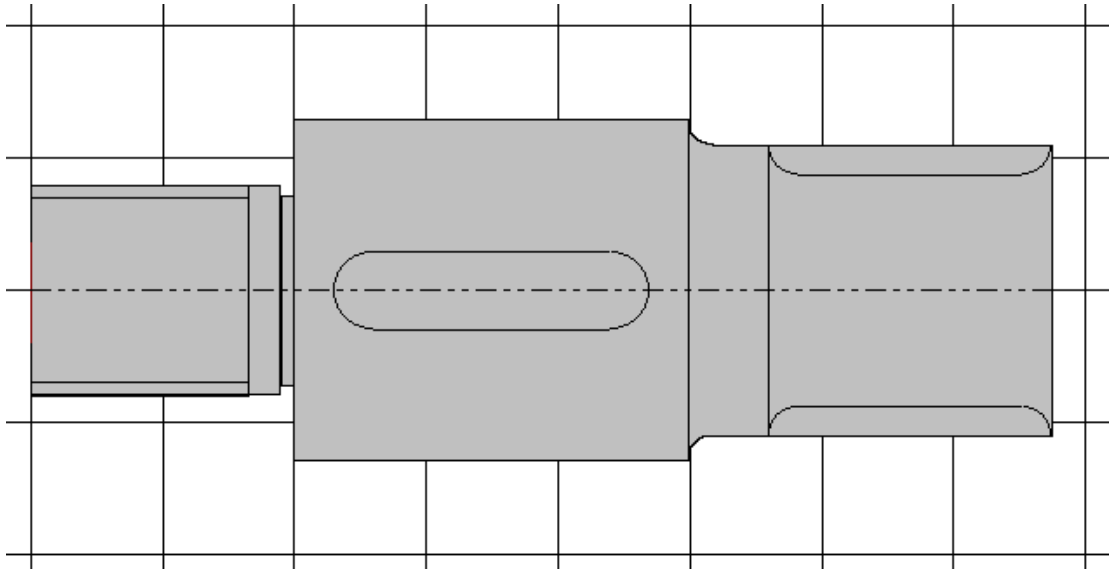


Fig. 2.7 APM Shaft editor. Shaft fragment with thread, key and spline joints.

## Splines

Spline joints are used to transmit torque between shaft and part mounted on it. When you want to draw spline joint you should first select spline type in the menu **Draw | Spline**. Then place cursor in the point that corresponds to either left or right edge of spline and press the left button. Holding the button, move cursor the other boundary of spline (when you move the cursor, a rectangle showing dimensions of the spline is displayed) and then release the button. Dialog box will be displayed where you can enter more accurate parameters of spline joint.

## Threaded zones

Threaded zones (see fig. 2.7) can be entered in the same way as a key and spline joints. First, specify one boundary, then the other and finally enter the parameters in the dialog window.

## Openings

Shaft editor allows to draw axial openings. You can enter two openings that start on the left and right edge surfaces of the shaft. The openings can be stepped. They are drawn in the same way as cylinder sections of the shaft (see above).

## Loads

Using shaft editor you can enter radial and axial forces, distributed forces, as well as bending moments and moments of torsion.

## Radial forces

Radial forces are acted along the normal to the shaft axis. To enter a radial force place cursor in the point where this force should be applied and click the left button. Dialog box will be displayed on the screen (fig. 2.8). Radial force is characterized by axial coordinate (the distance from the left end of the shaft), direction and amplitude. The latter two parameters you can enter in two ways. In the first case, you enter force module and the angle between force direction and vertical; these parameters should be typed in the *Module* and *Angle* edit boxes. In the second case, you have to enter force projections in the *Vertical* and *Horizontal* edit boxes. To switch between these two modes use *Module* and *Projections* radio buttons. You can specify identifier of the force that consist of two parts—name and index that are entered in the respective edit boxes. Examples of identifiers are  $F_1$ ,  $Weight_{ofEngine}$ , etc.

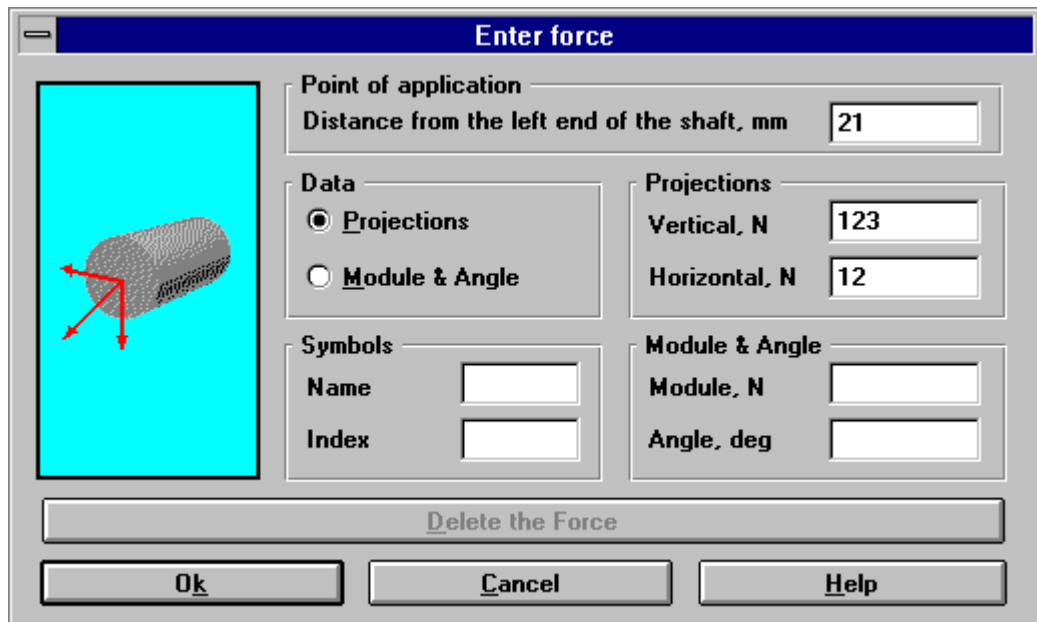


Fig. 2.8 Dialog box for radial forces entering and editing.

### Axial forces

To enter axial force you should click the left button in the point of application of the force. Dialog box will be shown on screen where you have to enter force value.

### Distributed forces

Distributed force is characterized by the zone it acted upon and by the values of specific pressure on the left and right ends of this zone (to determine values in the inner parts of the zone linear interpolation is used). To enter distributed force place cursor on the one of its boundaries (left or right, it doesn't matter) and press mouse left button. Holding the button move cursor to the other boundary and release button. Dialog box will be displayed (fig. 2.9), where you can specify more accurate coordinates of boundaries and enter specific pressures acting at these boundaries.



Fig. 2.9 Dialog box for distributed force entering and editing

### Bending moments

Moment of bending is entered in the same manner as a radial force. After you click the left button in the point of application of the moment, the dialog box will be displayed that allows to specify moment of bending either through vertical and horizontal projections or through module and angle (fig. 2.10).



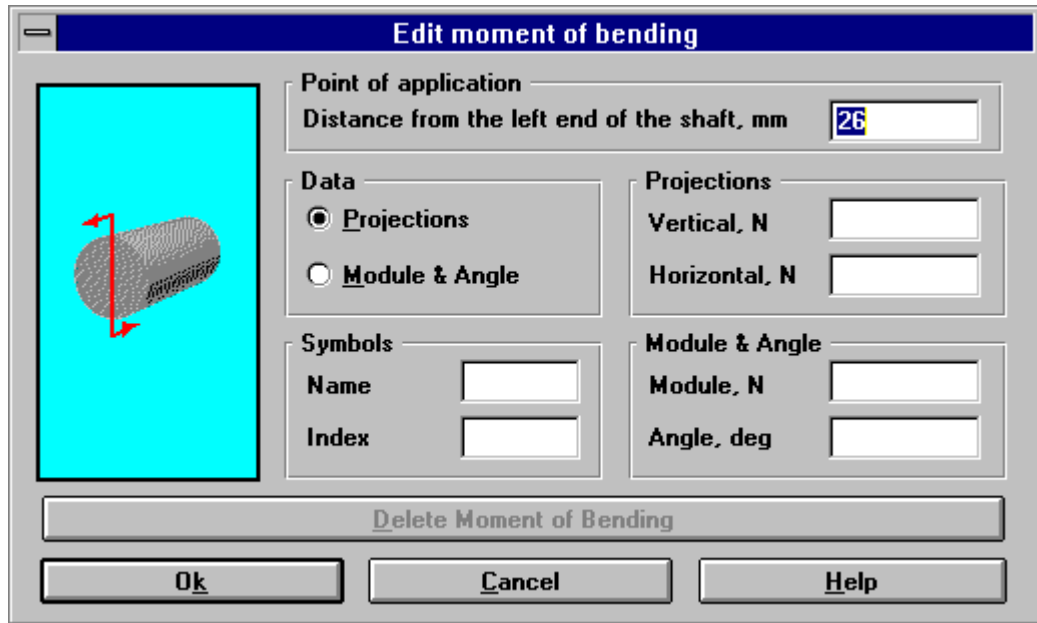


Fig. 2.10. Dialog box for bending moment entering and editing

## Moments of torsion

Moment of torsion is characterized by its value and point of application. To enter it, place cursor on the point of application of the moment and then click the left button. In the dialog box displayed (fig. 2.11), enter the module of moment of torsion.

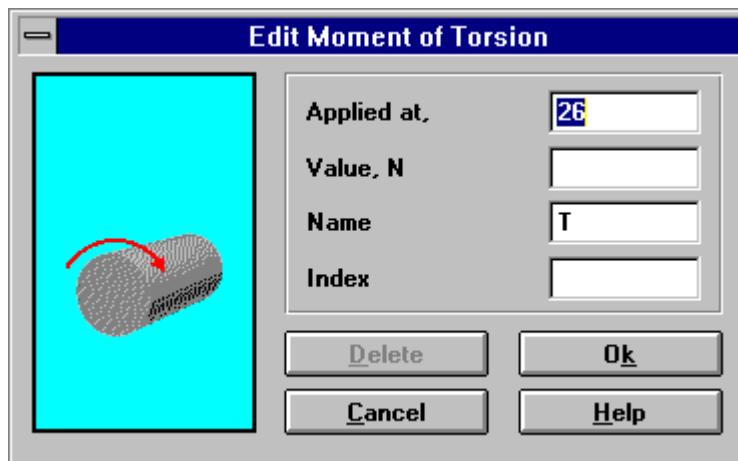


Fig. 2.11. Dialog box for torsion moment entering and editing

## Bases

There are four bases types in APM Shaft editor—immovable, movable in axial direction, elastic, hinged movable. Select **Draw | Base** command to switch editor in base drawing mode. Then click the left button in the point you want to place a base. Dialog box for the base type and coordinate will be displayed (fig. 2.12).

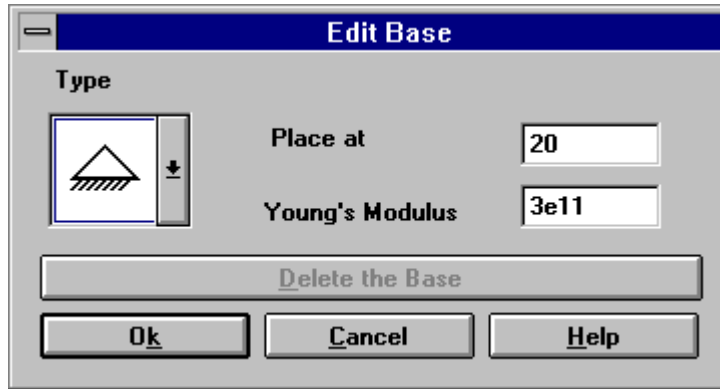


Fig. 2.12. Dialog box for base entering and editing

## Material properties

To calculate shaft it is necessary to specify the properties of material of the shaft. These are breaking strength, Young's modulus, Poisson's ratio. You can enter these parameters in one of the following ways:

- to select from the APM WinMachine data base (**Material | Data Base** command)
- to enter in the dialog box (**Material | User Data** command)

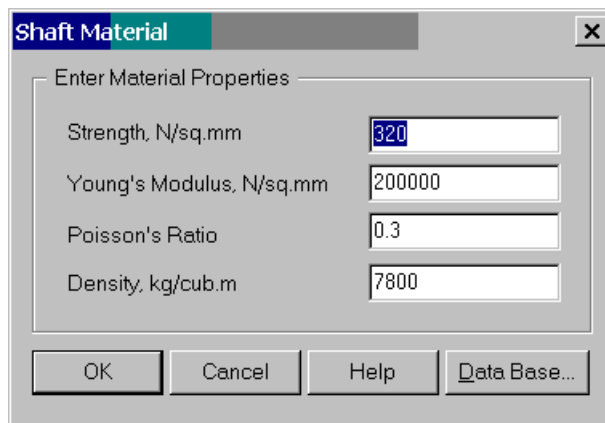


Fig. 2.13 Dialog box for shaft's material specification

## Variable Load

APM Shaft allows you to specify variable regime of shaft loads. You can enter it selecting **Variable Load** command that invoke a dialog for operation regime selection. Some predefined operation regimes are available. If *User type* is selected variable load regime editor will be displayed after OK pressing. The editor represents dialog window there you can draw graph of required regime by points. In fig. 2.14. the window of the load regime editor is shown.

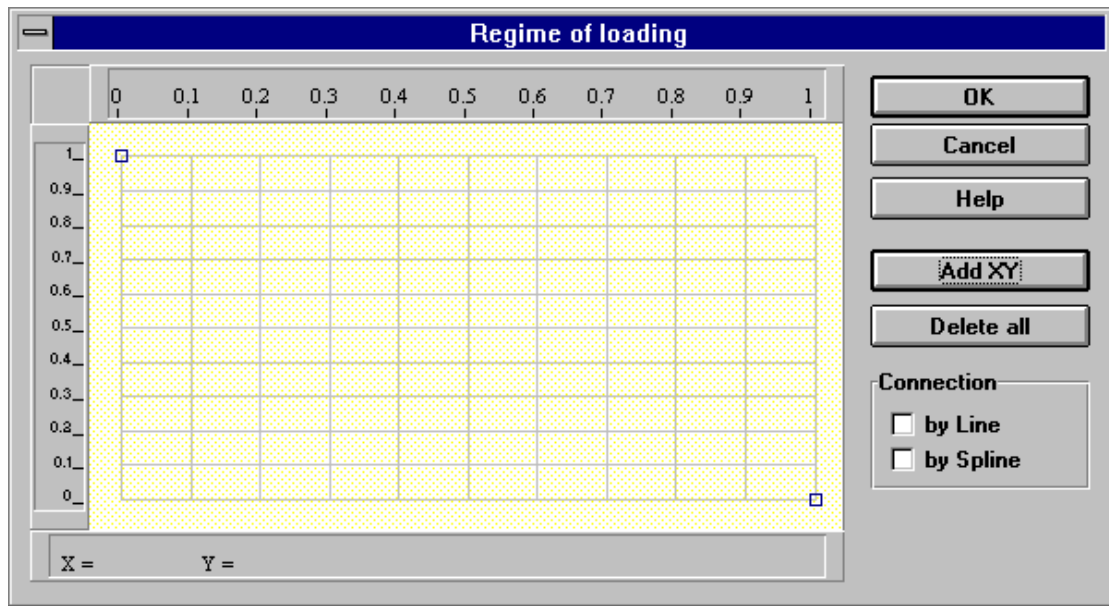


Fig. 2.14 Editor of load regime

## Working time

To make shaft calculation on fatigue strength it is necessary to specify the number of load cycles. To do it you should enter shaft longevity and its revolution in the displayed just before calculation dialog box .

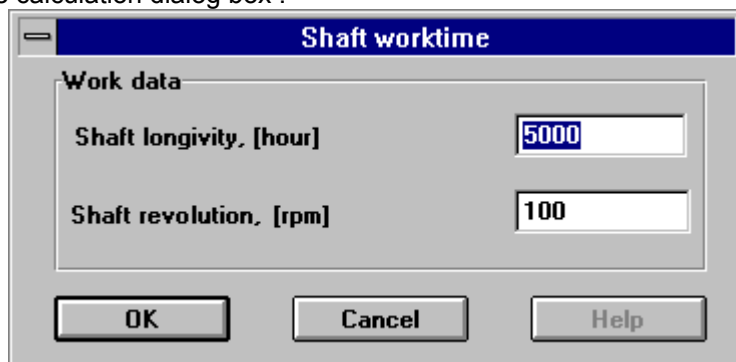


Fig. 2.15 Dialog box for number of load cycles entering

## Shaft deletion

To delete the shaft use **Draw | Delete** command. You have to confirm your intention in the dialog box that will be shown.

## Chapter 3 APM Shaft Command Reference

In this chapter a complete description of each menu command and dialog box option in **APM Shaft** environment is given. Shaft editor commands are described in details in chapter 2.

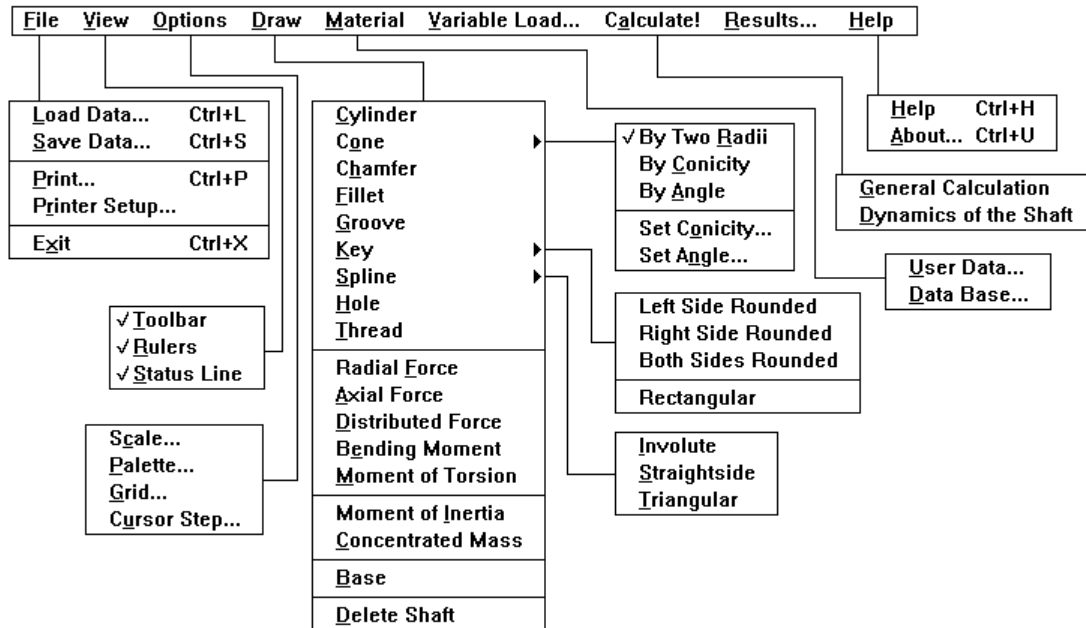


Fig. 3.1 APM Shaft menu structure.

### File Menu

Menu **File** contains commands for creating and loading archive files, printing initial data and calculation results.

<b>L</b> oad Data...	<b>C</b> trl+L
<b>S</b> ave Data...	<b>C</b> trl+S
<b>P</b> rint...	<b>C</b> trl+P
<b>P</b> rinter Setup...	
<b>E</b> xit	<b>C</b> trl+X

Fig 3.2 File popup menu.

### Load Command

**File | Load** command lets you load previously created archive file. As a response to this command the standard dialog box, used in Microsoft Windows for file opening appears on the screen (see fig. 3.3). In this dialog box you should choose archive file you want to load.

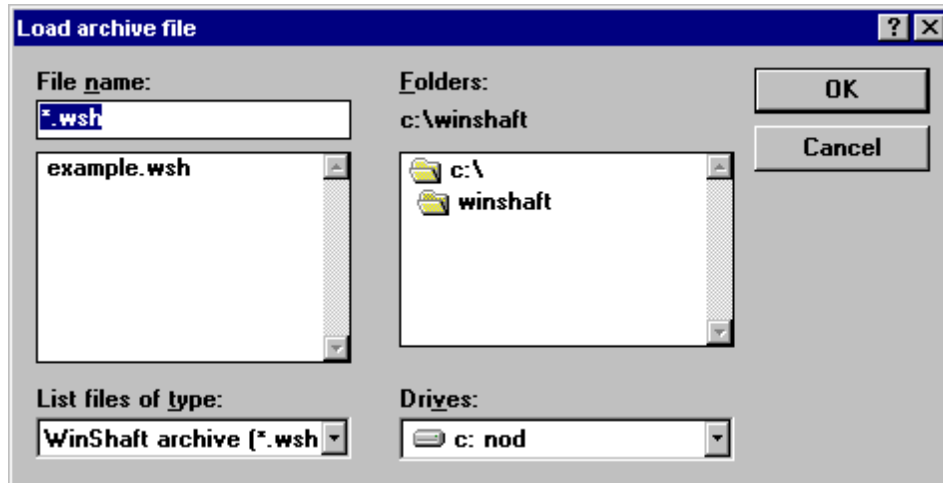


Fig 3.3 *Load archive file* Dialog box.

### **Save Command**

With **File | Save** command you can create archive files in which initial data and calculation results will be saved. Later you can load this file and continue your work with object, stored in this file. After choosing this command, the dialog box where you should enter archive file name (fig. 3.3) appears on the screen.

### **Print Command**

Using **File | Print** command you can print shaft scheme.

### **Printer Setup Command**

**File | Printer Setup** command lets you choose printer type and its settings. At command printer setup dialog box appears on the screen, its contents depends on printer you are using.

### **Exit Command**

**File | Exit** terminates the program.

### **View Menu**

**View** popup menu contains commands defining the visibility of system elements and auxiliary grid.

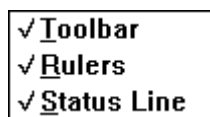


Fig 3.4 *View popup menu*.

### **Toolbar Command**

**View | Toolbar** command lets you hide the toolbar. The same command returns the toolbar back to the screen.

### **Rulers Command**

**View | Rulers** command hides and displays the rulers.

### **Status Line Command**

**View | Status Line** command hides and displays the status line.

## Options Menu

**Options** menu commands let you change the system settings such as drawing scale, palette, auxiliary grid type and step, cursor step.

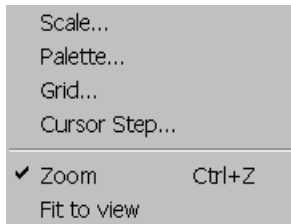


Fig 3.5 **Options** popup menu

## Scale Command

**Options** | **Scale** command calls dialog box for shaft drawing scale setting (fig 3.6). This dialog box includes edit box *Set Scale*, where you can enter desired scale and a number of buttons that set some of the most frequently used scale factors (1 : 2, 1 : 5, 1 : 10 etc).

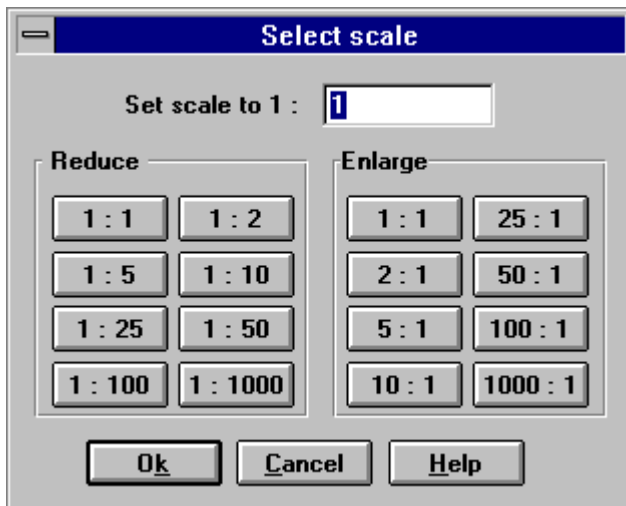


Fig 3.6 **Select Scale** dialog box

## Command Palette

**Options** | **Palette** command calls dialog box (Fig 3.7), where you can select palette, used for shaft painting. Palette is a color set, used for drawing individual elements of the shaft and components of the shaft editor.



Fig 3.7 **Set Editor Palette** dialog box.

## Grid Command

**Options** | **Grid** command calls dialog box for setting auxiliary grid parameters (fig 3.8). In this dialog box you can enter the grid steps in horizontal and vertical directions and select grid line type (dashed, solid, dotted). "No grid" mode is also available.

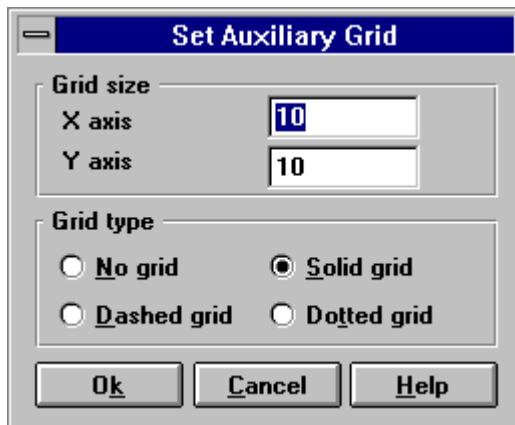


Fig 3.8 *Set Auxiliary Grid* dialog box.

### ***Cursor Step Command***

**Options | Cursor Step** command calls dialog box (fig 3.9) where accuracy of coordinates and dimensions entered with mouse can be changed.



Fig 3.9 *Set Cursor Step* dialog box.

### ***Zoom Command***

**Options | Zoom** command switches the shaft editor into zoom by rectangle mode. Click left mouse button and drag to point zoom rectangle diagonal.

### ***Fit to view Command***

**Options | Fit to view** command fit shaft to editor window.

### ***Draw Menu***

**Draw** menu contains commands controlling the work of the shaft editor. Each command switches the editor into the mode of drawing/editing of the respective shaft element, load or base. Shaft editor is described in details in chapter 2.

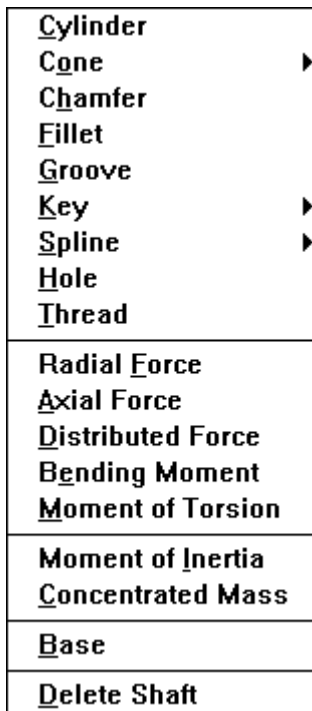


Fig 3.9 *Draw* popup menu

### ***Cylinder* Command**

**Draw | Cylinder** command switches the shaft editor into the mode of drawing cylindrical sections of the shaft.

### ***Cone* Menu**

**Draw | Cone** command invokes popup menu **Cone** (Fig 3.10).

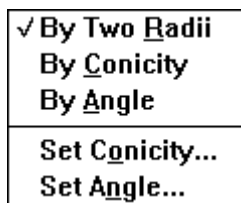


Fig 3.10 *Cone* popup menu

### ***By Two Radii* Command**

**Draw | Cone | By Two Radii** command switches the shaft editor into the mode of drawing conical sections of the shaft by its initial and final radius.

### ***By Conicity* Command**

**Draw | Cone | By Conicity** command switches the shaft editor into the mode of drawing conical sections of the shaft by current value of the conicity. For setting conicity **Draw | Cone | Set Conicity** command is used.

### ***By Angle* Command**

**Draw | Cone | By Angle** command switches the shaft editor into the mode of drawing conical sections of the shaft by current value of the cone angle (angle between cone line and shaft axis). For setting cone angle **Draw | Cone | Set Angle** command is used.



### ***Set Conicity... Command***

**Draw | Cone | Set Conicity...** command calls dialog box for entering current value of conicity. This value is used for drawing conical sections by given conicity.

### ***Set Angle... Command***

**Draw | Cone | Set Angle...** command invokes dialog box for entering current value of cone angle. This value is used for drawing conical sections by given angle.

### ***Chamfer Command***

**Draw | Chamfer** command switches the shaft editor into the mode of entering the chamfers.

### ***Fillet Command***

**Draw | Fillet** command switches shaft editor into the mode of entering the fillets.

### ***Groove Command***

**Draw | Groove** command switches shaft editor into the mode of entering the grooves.

### ***Key Menu***

**Draw | Key** command invokes **Key** popup menu (Fig 3.11 ).



Fig 3.11 **Key** dialog box

### ***Left Side Rounded Command***

**Draw | Key | Left Side Rounded** command switches the shaft editor into the mode of drawing keys, beginning on the right side of a section and having a rounding on the left.

### ***Right Side Rounded Command***

**Draw | Key | Right Side Rounded** command switches the shaft editor into the mode of drawing keys, beginning on the left side of a section and having a rounding on the right.

### ***Both Sides Rounded Command***

**Draw | Key | Both Sides Rounded** command switches the shaft editor into the mode of drawing keys, having a roundings on both ends.

### ***Rectangular Command***

**Draw | Key | Rectangular** command switches the shaft editor into the mode of drawing the rectangular keys.

### ***Spline Menu***

**Draw | Spline** command calls popup menu **Spline** (Fig 3.12).

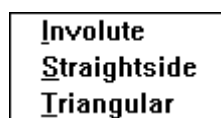


Fig 3.12 **Spline** popup menu

### ***Involute Command***

**Draw | Spline | Involute** command switches the shaft editor into the mode of drawing the involute splines.

### ***Straightside Command***

**Draw | Spline | Straightside** command switches the shaft editor into the mode of drawing the straitside splines.

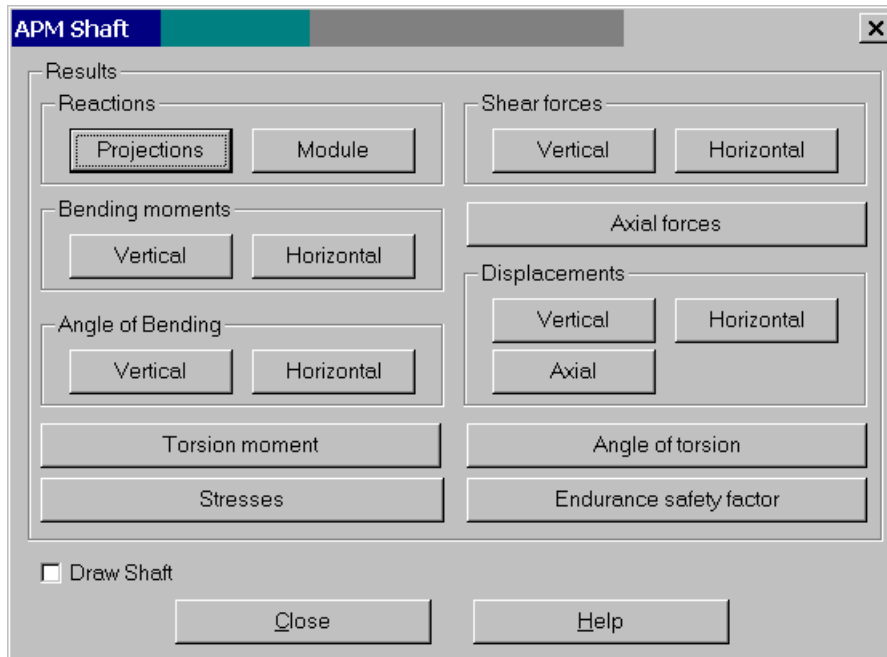


Fig 3.13. The Results dialog box

### ***Triangular Command***

**Draw | Spline | Triangular** command switches the shaft editor into the mode of drawing the triangular splines.

### ***Hole Command***

**Draw | Hole** command switches the shaft editor into the mode of drawing the axial holes.

### ***Thread Command***

**Draw | Thread** command switches the shaft editor into the mode of specifying sections with thread.

### ***Radial Force Command***

**Draw | Radial Force** switches the shaft editor into the mode of entering the radial forces. To enter a radial force you should place cursor on point of application of the force and click the left button. In the dialog box displayed you should enter parameters characterizing the force.

### ***Axial Force Command***

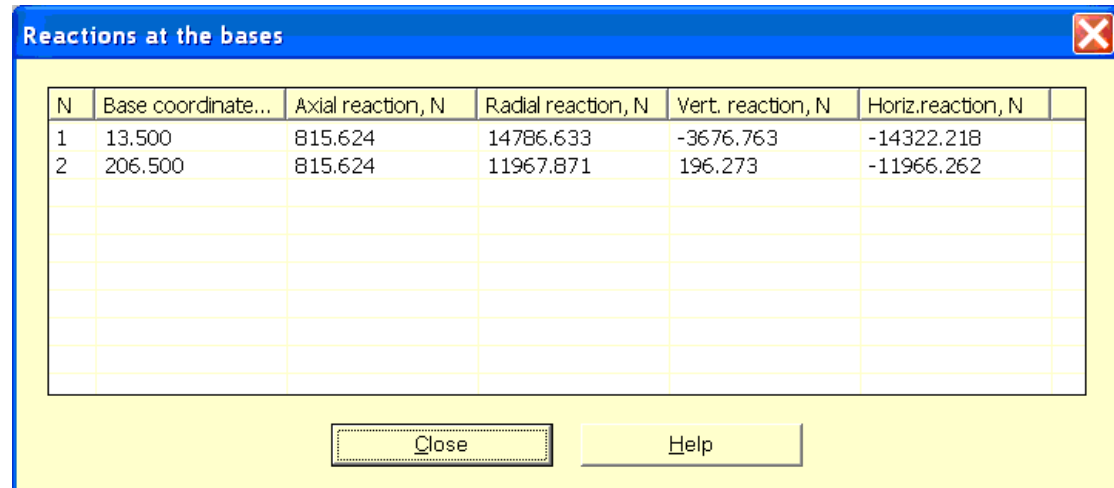
**Draw | Axial Force** command switches the shaft editor into the mode of entering the axial forces.

### ***Distributed force Command***

**Draw | Axial Force** command switches the shaft editor into the mode of entering the distributed forces.

### ***Bending Moment Command***

**Draw | Axial Force** command switches the shaft editor into the mode of entering the bending moments.



N	Base coordinate...	Axial reaction, N	Radial reaction, N	Vert. reaction, N	Horiz.reaction, N
1	13.500	815.624	14786.633	-3676.763	-14322.218
2	206.500	815.624	11967.871	196.273	-11966.262

Fig 3.14. Results of calculation of reactions in shaft bases.

### ***Moment of torsion Command***

**Draw | Axial Force** command switches the shaft editor into the mode of entering the torsion moment.

### ***Base Command***

**Draw | Axial Force** command switches the shaft editor into the base entering mode.

### ***Delete Shaft Command***

**Draw | Axial Force** command deletes the shaft.

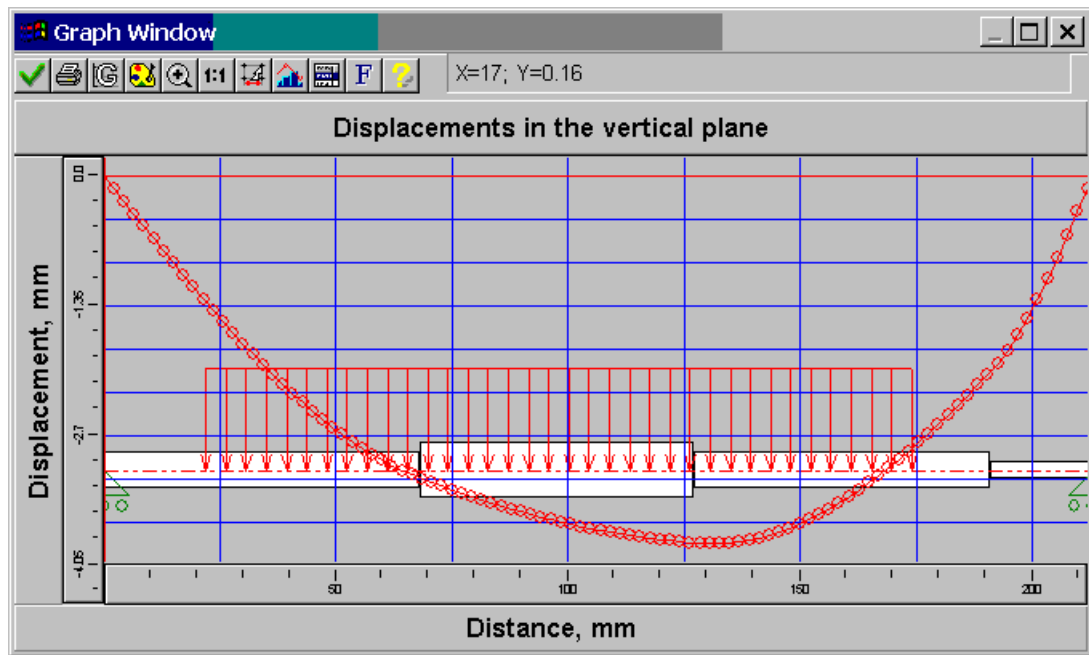


Fig 3.15. Graph of displacement in vertical plane.

### **Material popup menu**

Popup menu **Material** includes commands that allow you to enter the properties of the shaft material.

### **Parameters command**

**Material | User Data** command invokes the dialog box for entering the properties of the material.

### **Data base command**

**Material | Data Base** command allows you to select material for the shaft manufacturing and its properties from the database included in the **APM WinMachine**.

### **Variable Load command**

This command invokes the editor for specifying load regime.

### **Calculate! | General Calculation command**

The **Calculate! | General Calculation** command performs shaft calculations on static and fatigue strength. The calculation results are distributions of internal load factors, equivalent stresses and endurance safety factor.

### **Calculate! | Dynamics of Shaft command**

The **Calculate! | Dynamics of Shaft** command performs calculations of shaft eigen frequencies and eigen shapes of bending and torsion vibrations.

### **Results command**

**Results** command displays the dialog box for calculation results demonstration. Buttons of this dialog box display corresponding topics either as a graph or as a table.

### **Help menu**

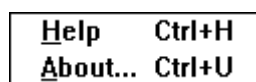


Fig. 3.16 Help popup menu

***Contents* command**

**Help | Contents** command displays **APM Shaft** help contents.

***About* command**

**Help | About** command displays window with information about program and license holder.

## Index

### *A*

Axial forces ..... 15

### *B*

Bases ..... 16

Bending moments ..... 15

### *C*

Chamfers ..... 12

Cone section drawing ..... 11

Cylinder section drawing ..... 9

### *D*

Distributed forces ..... 15

### *F*

Fillets ..... 12

### *G*

Grooves ..... 13

### *K*

Keys ..... 13

### *L*

Loads Entering ..... 14

### *M*

Material properties ..... 17

Moments of torsion ..... 16

### *O*

Openings ..... 14

### *R*

Radial forces ..... 14

### *S*

Shaft deletion ..... 18

Shaft drawing ..... 8

Shaft Editing ..... 9

Shaft editor ..... 7

Splines ..... 14

Structure and main elements of a graphics ..... 29

### *T*

Threaded zones ..... 14

### *V*

Variable Load ..... 17

### *W*

Working time ..... 18

## Figures

2.1: Adding of the new sections to the shaft.....	10
2.2: Dialog box for editing the shaft section parameters .....	11
2.3: Cone drawing by start and end radi .....	11
2.4: Shaft fragment with chamfers, fillets and groove .....	12
2.5: Dialog box for groove type selection .....	13
2.6: Dialog box for groove parameters setting .....	13
2.7: Shaft fragment with thread, key and spline joints.....	14
2.8: Dialog box for radial forces entering and editing .....	15
2.9: Dialog box for distributed force entering and editing.....	15
2.10: Dialog box for bending moment entering and editing.....	16
2.11: Dialog box for torsion moment entering and editing.....	16
2.12: Dialog box for base entering and editing.....	17
2.13: Dialog box for shaft's material specification .....	17
2.14: Editor of load regime .....	18
2.15: Dialog box for number of load cycles entering .....	18
3.1: APM Shaft menu structure .....	19
3.2: File popup menu.....	19
3.3: Load archive file Dialog box .....	20
3.4: View popup menu.....	20
3.5: Options popup menu .....	21
3.6: Select Scale dialog box .....	21
3.7: Set Editor Palette dialog box .....	21
3.8: Set Auxiliary Grid dialog box .....	22
3.9: Set Cursor Step dialog box .....	22

3.9: Draw popup menu .....	23
3.10: Cone popup menu .....	23
3.11: Key dialog box .....	24
3.12: Spline popup menu .....	25
3.13: The Results dialog box .....	25
3.14: Results of calculation of reactions in shaft bases .....	26
3.15: Graphics of deformation in vertical plane .....	27
3.15: Help popup menu .....	28
4.1: General view of graphics representation system .....	29
4.2: Menu structure of graphics drawing system .....	30
4.3: Graphics Layout dialog box .....	31
4.4: Graphics Title dialog box .....	31
4.5: Select Font dialog box .....	32
4.6: Text Orientation dialog box .....	32
4.7: Text Displaying Style dialog box .....	33
4.8: Text Preview dialog box .....	33
4.9: Scale Axes dialog box .....	34
4.10: Vertical axes planning dialog box .....	34
4.11: Graphics Displaying Style dialog box .....	35
4.12: Graphics Points Color .....	35
4.13: Color Selection dialog box .....	36
4.14: Color Palette Editor dialog box .....	36
4.15: Graphics Line style dialog box .....	37
4.16: Interactive Selection Options dialog box .....	38

## Contents

Introduction .....	3
APM Shaft—what is it? .....	3
Hardware and software requirements .....	3
Installing APM Shaft .....	3
What's in this manual .....	3
Typefaces used in this book .....	4
How to contact APM .....	4
Chapter 1 Problems, initial data and results .....	5
Shafts: purpose and classification .....	5
Calculation of the shafts .....	5
Static strength calculation .....	5
Fatigue strength calculation .....	6
Calculation of stiffness .....	6
Chapter 2 Shaft editor .....	7
Editor layout .....	7
Editor window .....	7
Rulers .....	7
Status line .....	7
Toolbar .....	7
Scrolling and scroll bars .....	7
Editor window enlarging .....	7
Scaling .....	8
Palette editor .....	8
Auxiliary grid .....	8
Cursor step .....	8
Basic principles of editor .....	8

Mode selection .....	8
Shaft drawing.....	8
Editing.....	9
Diagnostics .....	9
Shaft elements .....	9
Cylinder section drawing .....	9
Editing and deletion of cylinder and cone sections .....	10
Cone section drawing.....	11
Fillets .....	12
Chamfers .....	12
Grooves .....	13
Keys.....	13
Splines.....	14
Threaded zones .....	14
Openings .....	14
Loads.....	14
Radial forces.....	14
Axial forces .....	15
Distributed forces .....	15
Bending moments .....	15
Moments of torsion.....	16
Bases.....	16
Material properties.....	17
Variable Load .....	17
Working time.....	18
Shaft deletion.....	18
Chapter 3 APM Shaft Command Reference .....	19
<i>File</i> Menu.....	19
<i>Load</i> Command .....	19
<i>Save</i> Command.....	20
<i>Print</i> Command.....	20
<i>Printer Setup</i> Command.....	20
<i>Exit</i> Command .....	20
<i>View</i> Menu .....	20
<i>Toolbar</i> Command.....	20
<i>Rulers</i> Command .....	20
<i>Status Line</i> Command.....	20
<i>Options</i> Menu .....	21
<i>Scale</i> Command .....	21
<i>Command Palette</i> .....	21
<i>Grid</i> Command .....	21
<i>Cursor Step</i> Command.....	22
<i>Draw</i> Menu .....	22
<i>Cylinder</i> Command.....	23
<i>Cone</i> Menu.....	23
<i>By Two Radii</i> Command.....	23
<i>By Conicity</i> Command.....	23
<i>By Angle</i> Command .....	23
<i>Set Conicity...</i> Command.....	24
<i>Set Angle...</i> Command .....	24
<i>Chamfer</i> Command .....	24
<i>Fillet</i> Command .....	24
<i>Groove</i> Command .....	24
<i>Key</i> Menu .....	24
<i>Left Side Rounded</i> Command.....	24
<i>Right Side Rounded</i> Command.....	24
<i>Both Sides Rounded</i> Command.....	24
<i>Rectangular</i> Command .....	24
<i>Spline</i> Menu.....	24



<i>Involute</i> Command .....	25
<i>Straightside</i> Command .....	25
<i>Triangular</i> Command .....	25
<i>Hole</i> Command .....	25
<i>Thread</i> Command .....	25
<i>Radial Force</i> Command .....	25
<i>Axial Force</i> Command .....	26
<i>Distributed force</i> Command .....	26
<i>Bending Moment</i> Command .....	26
<i>Moment of torsion</i> Command .....	26
<i>Base</i> Command .....	26
<i>Delete Shaft</i> Command .....	26
<i>Material</i> popup menu .....	27
<i>Parameters</i> command .....	27
<i>Data base</i> command .....	27
<i>Variable Load</i> command .....	27
<i>Calculate!</i>   <i>General Calculation</i> command .....	27
<i>Calculate!</i>   <i>Dynamics of Shaft</i> command .....	27
<i>Results</i> command .....	27
<i>Help</i> menu .....	28
<i>Contents</i> command .....	28
<i>About</i> command .....	28
Chapter 4 Graphics representation system .....	29
Purpose and possibility .....	29
Structure and main elements of a graphics .....	29
Command Reference .....	30
<i>File</i> menu .....	30
<i>Open</i> Command .....	30
<i>Save</i> Command .....	30
<i>Exit</i> Command .....	30
Graphics menu .....	30
<i>Graphics Layout</i> Command .....	30
<i>Graphics Title</i> command .....	31
<i>Scale Axes</i> command .....	33
<i>Vertical Axes</i> command .....	34
<i>Horizontal Axes</i> command .....	34
<i>Style</i> menu .....	34
<i>Graphics style</i> command .....	34
<i>Graphics of Points, Linear Graph, Filled Graph, Column Chart</i> commands .....	36
<i>Graphics Title</i> command .....	37
<i>Graphics desktop, Graphics Background</i> commands .....	37
<i>Line Style</i>   <i>Graphics Line, Line Style</i>   <i>Outline</i> commands .....	37
<i>Edit</i> menu .....	37
<i>Resize graphics field</i> command .....	37
<i>Options</i> menu .....	37
<i>Save Settings on Exit</i> command .....	37
<i>Interactive selection</i> command .....	37
Index .....	i
Figures .....	i
Contents .....	ii