

APM Plain

User's Guide

APM Plain

The system for plain bearing calculation

Version 9.0

User's Guide

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Introduction

APM Plain—what is it?

APM Plain is the system for plain bearing calculation developed in the APM Ltd Research and Software Development Center.

Using **APM Plain** you can calculate plain bearings of the following types:

- radial bearing of complete lubrication
- radial bearing of incomplete lubrication
- thrust bearing of complete lubrication

With **APM Plain** the most important bearing parameters can be calculated including:

- clearance distribution,
- oil consumption,
- average and maximum oil temperature,
- loss of power,
- axial beatings, etc.

Hardware and software requirements

Hardware minimum: Pentium 266 MHz, RAM 64 Mb. Software: MS Windows-9X ,Me; MS Windows-NT(SP-6), 2000, XP.

What's in this manual

Introduction (this section) tells you what APM Plain is in general, what parameters and what types of bearings could be calculated. You will know the requirements to hardware and system software are listed.

Chapter 1, Problems, initial data and results contains description of the problems solved with APM Plain. The strict definitions of all calculated parameters and initial data are given. Presentation of the results is described.

Chapter 2, Command reference contains complete description of all commands of the main menu and popup menus.

In the **Appendix** warnings and error messages generated by APM Plain are listed.

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).
SETUP.EXE	We use all capital letters for the names of files and keys.
Help	APM Plain command names are shown in boldface.
<i>Results</i>	Italics is used for the names of dialog boxes and controls

How to contact APM

To contact APM you can use one of the following ways:

Send fax. Our Moscow fax number is +7(495) 585-06-11.

Call by phone +7(495) 585-06-11 (Moscow) or +7(495) 514-84-19 (Moscow).

Write a letter and send it to

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

Use E-mail: com@apm.ru, com@apmwm.com.

Visit our web-site: <http://www.apm.ru>, <http://www.apmwm.com>.

Chapter 1

Problems, initial data and results

Bearing is a shaft support, that takes the load, applied to the shaft and provides its rotation. Depending on the mode of friction all bearings are divided into two main groups—rolling contact bearings and plain bearings. In the former rolling friction take place, whereas in the latter—sliding friction. In the plain bearing the shaft and the shell are separated with a film of liquid. Usually oil is used for the purpose, in special cases other liquids can be used.

The optimum operation mode of those bearings is that of complete liquid lubrication. It prevents the contact of the elements and their wearing and minimizes friction coefficient.

When oil film has breaks and relative movement of bearing elements is accompanying with their contact, corresponded mode is called semi-liquid lubrication mode. This mode increases wearing and heat release, it is accompanied with high energy losses and risk of fretting's appearance. In contrast to latter the complete liquid lubrication mode requires forced oil supply, that considerably limits it's application. In some constructions plain bearings don't require lubrication since they are manufactured of metal materials with low friction coefficient and high wear resistance. This operating mode is called dry friction mode.

APM Plain is intended for complete design of plain bearing. In the system checking calculations are implemented, i.e. we determine main output characteristics for bearing with given dimensions, given loads applied and produced of given material.

With APM Plain you can calculate the following types of plain bearings:

- radial bearings with complete liquid lubrication
- radial bearings with semi-liquid lubrication
- thrust bearings with complete liquid lubrication

Complete liquid lubrication mode

Load-carrying capacity of bearing running in this mode is determined through laminar flow problem solution for sliding support. The method includes corrections that take into account oil leakage through the end faces. Sliding support is considered appropriate if the minimum clearance in working state is greater then the sum of heights of microroughness of the shaft and shell by 1.5 times and more. Also oil temperature is calculated from the equation of heat balance; it must be less than allowable value for chosen oil brand.

If conditions listed above are not satisfied, then either bearing dimensions should be changed or forced cooling should be used.

Semi-liquid lubrication mode.

Methods of load-carrying capacity calculation for plain bearing running in semi-liquid lubrication mode are based on the experimental data relating contact interaction of surfaces being in relative movement in the presence of limited quantity of the oil. These problems include the friction problem as well as heat transfer problem, that is tied with the former. Moreover contact interaction is accompanying by wear, it's calculation will be included in the next version of the system.

By performing results analysis for a number of different variants it is possible to select the best one and to get rational construction of plain bearing.

Below we give a brief description of initial data and calculation results.

Bearing types

As mentioned above with **APM Plain** you can calculate the plain bearings of two types:

- radial bearings that operate in the modes of complete and incomplete lubrication
- thrust bearings

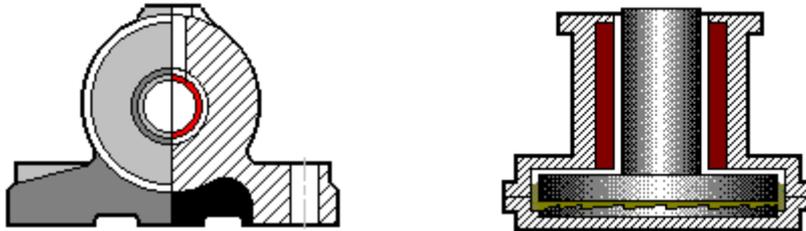


Fig. 1.1 Plain bearings of radial and thrust types

The initial data used to calculate plain bearings can be divided into three groups:

- geometry data
- data that characterize working conditions
- oil parameters

Geometry

This group includes dimensions of bearing and shaft as well as manufacturing errors of working surfaces.

Shaft diameter

The outer diameter of the shaft zone that takes oil pressure.
Measurement units - millimeters (mm).

Contact zone length

The length of the shaft zone that takes oil pressure.
Measurement units - millimeters (mm).

Outer diameter

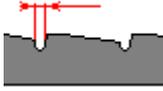
The diameter that define outer boundary of zone of hydrodynamic reaction.
Measurement units - millimeters (mm).

Inner diameter

The diameter that define inner boundary of zone of hydrodynamic reaction.
Measurement units - millimeters (mm).

Lubrication groove width

The width of groove included in the non-working zone.
Measurement units - millimeters (mm).

**Noncylindricity of the shaft**

Maximum distance between real surface of the shaft and adjusting cylinder.
Measurement units - millimeters (mm).

Nonperpendicularity to A, B

Perpendicularity error of referenced surfaces.
Measurement units - millimeters (mm).

Surface finish

Surface finish of working surfaces that depends on microroughness of shaft. As a measure of microroughness Ra value is used that is the mean value of profile deviation modulus along the base length.

Working conditions

To describe conditions plain bearing works at the following parameters are used:

Radial force

The force that is perpendicular to rotation axis and directed to rotation center.
Measurement units - Newton (N).

Axial force

The force directed along the shaft axis.
Measurement units - Newton (N).

Rotational speed

The number of shaft revolutions per unit time.
Measurement units - revolutions per minute (rpm).

Friction coefficient

The ratio of friction force to normal reaction that arises in the contact of conjugated bodies. This parameter is dimensionless.

Housing surface area

The area of outer surface of bearing housing.
Measurement units - square meters (sq.mm).

Environment temperature

The air temperature in the place the bearing is mounted.
Measurement units - Celsius degrees (deg).

Young's modulus

Modulus of elasticity.
Measurement units - megaPascals (MPa).

Maximum allowable load

The stress exceeding of which caused plastic deformations in the thrust bearing.
Measurement units - Pascals (MPa).

Oil temperature

Maximum temperature of oil film in stationary mode.
Measurement units - Celsius degrees (deg).

Oil feed pressure

Exceeding pressure of oil at the entry in the working zone of bearing.
Measurement units - Pascals (MPa).

Contact angle of oil film

The angle that determines the length of the working surface.
Measurement units - degrees (deg).



Minimum thickness of oil film

Minimum thickness of oil film in the working zone of bearing.
Measurement units - millimeters (mm).

Thermal conductivity

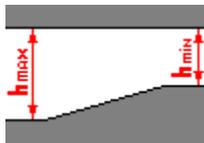
Heat transfer from more heated zones of a body to less heated ones.
Measurement units - Watt per square meter degree ($W/sq.m \times deg$).

The number of slopes

Construction parameter that determines the number of oil wedges balancing external load.

Inclination ratio

Construction parameter that is equal the ratio of maximum clearance to minimum one.



Oil parameters

To describe properties of oil used for bearing lubrication the following data are used:

Heat capacity

The quantity of heat absorbed by the body of unit mass during heating by one degree.
Measurement units - Joule per kilogram degree ($J/kg \times deg$).

Oil density

The mass of unit volume of material.
Measurement units - kilogram per cubic meter ($kg /cub.m$)

Viscosity

The ability of the liquid to resist relative displacement of its layers. Dynamic viscosity is equal to tangent stress that should be applied at the surface of the liquid in order to get unit gradient of layer displacement velocity.

Measurement units - Pascal seconds ($Pa \times sec$)

Oil feed method

Determine the method of oil feed: whether oil is directed to working zone or to non-working zone.

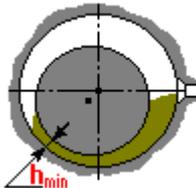
Results

Using **APM Plain** you can calculate the following parameters:

A) Radial bearing working in the complete lubrication mode

Minimum thickness of oil film - h_{min}

Minimum thickness of oil film between surfaces in contact.
Measurement units - millimeters (mm).



Critical thickness of oil film - h_{cr}

Minimum thickness of oil film thickness that leads to transition from mode of complete lubrication to mode of semi-liquid lubrication.
Measurement units - millimeters (mm).

Recommended radial clearance

The clearance that is optimum for efficient operating of bearing.
Measurement units - millimeters (mm).

Maximum oil temperature

Maximum temperature in the working zone of bearing.
Measurement units - Celsius degrees (deg).

Average oil temperature

Average temperature in the working zone of bearing.
Measurement units - Celsius degrees (deg).

Loss of power

The power require to surmount the action of friction forces in the bearing.
Measurement units - kilowatt (kWt).

Oil cosumption

The volume of oil that flows through the bearing per unit time.
Measurement units - cubic meter per second (cub. m/sec).

Radial clearance distribution

B) Radial bearing working in the incomplete lubrication mode:

True friction coefficient

True value of friction coefficient between shaft and shell.

Relative diameter clearance

The ratio of radial clearance to the diameter of the shaft.

Shell diameter

Inner diameter of bearing shell.
Measurement units - millimeters (mm).

Average oil temperature

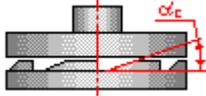
Average temperature in the working zone of bearing.
Measurement units - Celsius degrees (deg).

Average pressure in bearing

The ratio of average radial force to base area of bearing.
Measurement units - megaPascals (MPa).

C) Thrust bearing:**Slope angle - α_c**

Measurement units - degrees (deg).

**Average temperature of oil**

Average temperature in the working zone of bearing.
Measurement units - Celsius degrees (deg).

Minimum thickness of oil film

Minimum thickness of oil film thickness that leads to transition from mode of complete lubrication to mode of semi-liquid lubrication.

Measurement units - millimeters (mm).

Minimum thickness of oil film

Minimum thickness of oil film thickness that leads to transition from mode of complete lubrication to mode of semi-liquid lubrication.

Measurement units - millimeters (mm).

Complete oil consumption

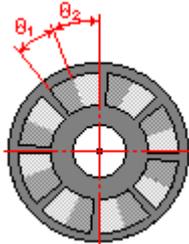
The volume of oil that flows through the bearing per unit time.
Measurement units - cubic meter per second (cub. m/sec).

The slope of plane area - θ_1

Measurement units - radians (rad).

Slope angle - θ_2

Measurement units - radians (rad).

**Radial clearance distribution**

Chapter 2

Command reference

This section includes a complete description of all menu commands and dialog box options in the **APM Plain** environment. Fig. 2.1 shows the main menu of the **APM Plain** and all the pulldown menus called from the main menu.

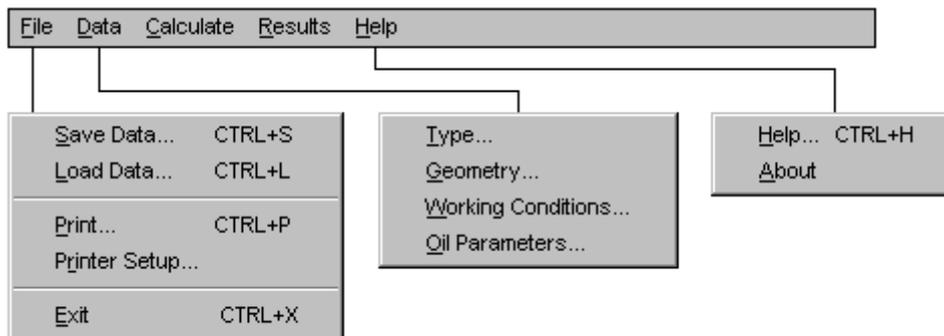


Figure 2.1 APM Plain menu structure

File menu

The **File** menu includes commands for

- loading information from archive files
- saving information to archive files
- printing initial data and calculation results
- choosing printer and printing options
- quitting the program

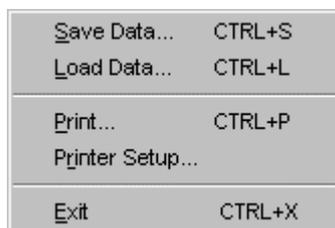


Fig. 2.2 The File menu

Save Data command

This command saves archive file by calling *Save Archive File* dialog box. See *Microsoft Windows User's Guide* to get more detail.

Load Data command

This command loads archive file by calling *Load Archive File* dialog box. See *Microsoft Windows User's Guide* for more information.

Print command

This command prints program resume. Print dialog box appears on the screen after choosing that command.

Print Setup command

This command lets you setup your printer. *Printer Setup* dialog box appears on the screen after choosing that. For more information see *Microsoft Windows User's Guide*.

Exit command

This command terminates the program.

Data menu

The **Data** command of the main menu invokes **Data** popup menu shown at Fig. 2.3. This menu contains commands that allow to enter initial data.

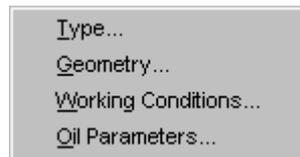


Fig. 2.3 The Data menu

Type command

This command lets you choose type of bearing to be calculated. *Select Bearing Type* dialog box appears on the screen (Fig.2.4).

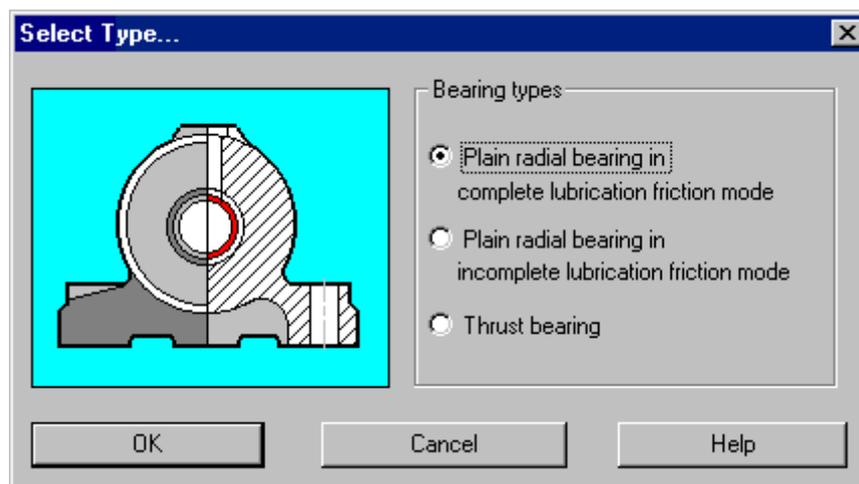


Fig. 2.4 The Select Bearing Type dialog box

Geometry command

This command lets you enter parameters concerning geometry of the bearing. *Bearing Geometry* dialog box appears on the screen (Fig.2.5). In this dialog box you can enter data that describe bearing dimensions and accuracy.

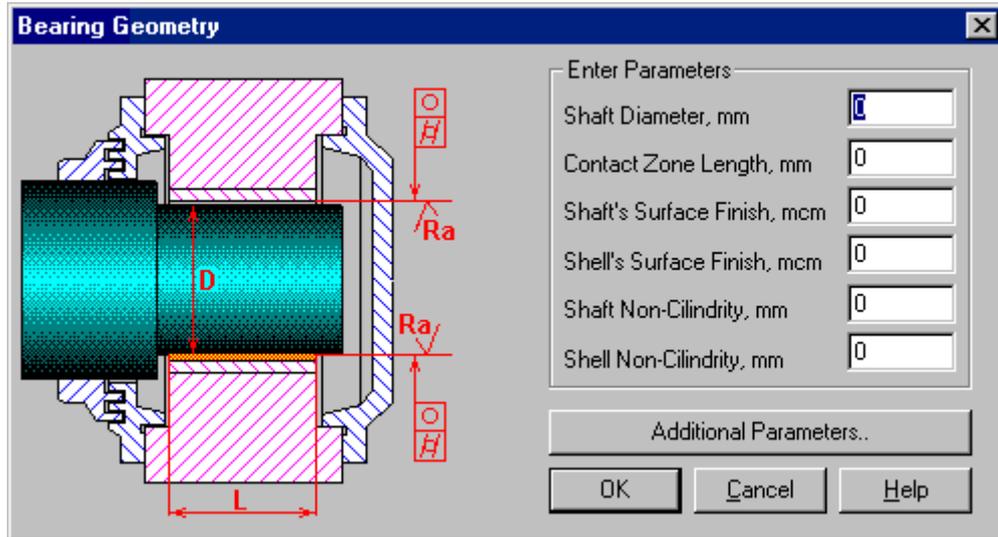


Fig. 2.5 Bearing Geometry dialog box

If you select *Additional Parameters...* button *Additional Parameters* dialog box appears on the screen (Fig.2.6). It allows you enter radial clearance. If you skip this step, clearance value will be determined by the program basing on geometry and working conditions. This value will be displayed in the *Results* dialog box.

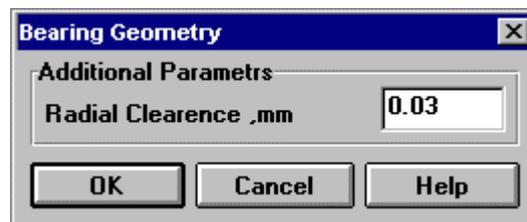


Fig. 2.6 Bearing Geometry (additional parameters) dialog box

Working Conditions command

This command lets you enter parameters concerning bearing working conditions. *Bearing Working Conditions* dialog box appears on the screen (Fig.2.7).

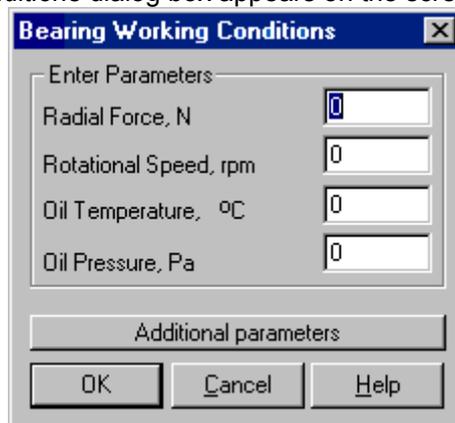


Fig. 2.7 Bearing Working Conditions dialog box

If you select *Additional Parameters...* button *Additional Parameters* dialog box appears on the screen. Using it you can change value of the contact angle of oil film (see Chapter 1). By default this parameter is set to 120 deg.

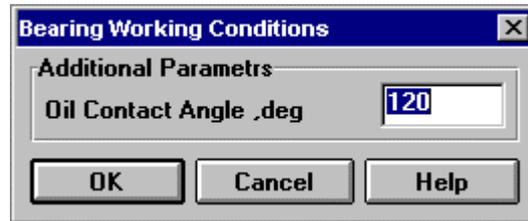


Fig. 2.8 Bearing Working Conditions (additional parameters) dialog box

Oil parameters command

This command lets you enter parameters concerning properties of oil used for lubrication. *Oil Parameters* dialog box appears on the screen (Fig.2.9).

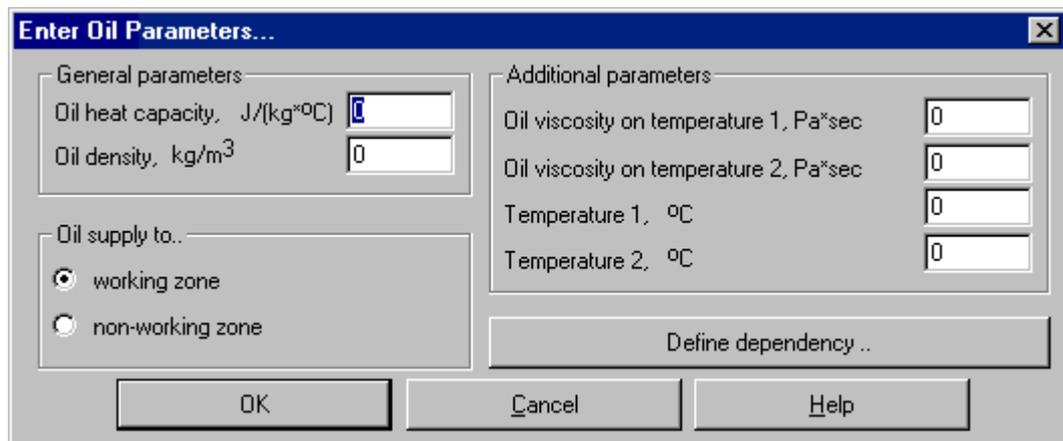


Fig. 2.9 The Oil Parameters dialog box

In the *General parameters* group you should enter heat capacity and density of the oil.

To specify dynamical viscosity you can use two ways—either by oil brand selecting or by entering two viscosity values that correspond to two different temperatures. To point out method of viscosity determination use radio buttons of *Data Type* group box. If you select *Oil Brand* button you should specify desired brand in the *Select Oil Brand* list box. When you have selected *Oil Parameters* button you should enter two values of viscosity that correspond to two different temperatures. You can enter these values immediately in the edit boxes of *Additional Parameters* group box. You can also define these values on the graph that is displayed if you select *Define Dependency* button.

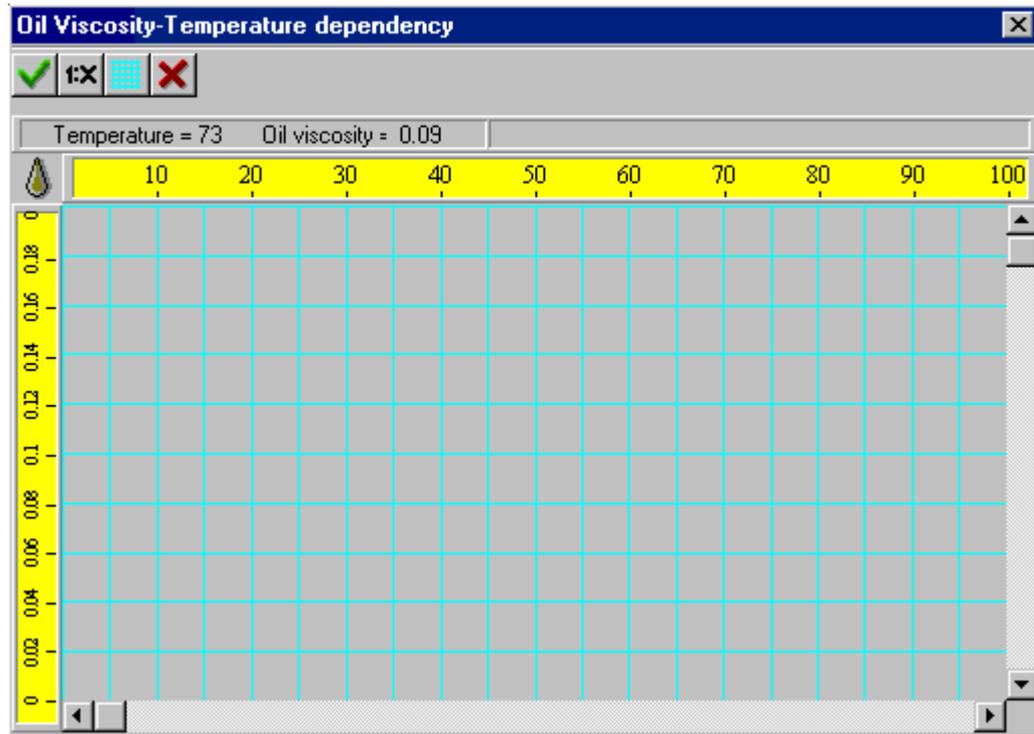


Fig. 2.10 The window used to determine Temperature—Viscosity dependence

The window used to specify Temperature—Viscosity dependence is shown in fig.2.10. Use mouse to enter two points that will be used to restore Temperature—Viscosity dependence.

The window includes rulers, scroll bars, status bar and toolbar. Horizontal ruler shows temperature in degrees, vertical one—dynamic viscosity in Pa x sec. Values of temperature and viscosity that correspond to current cursor position are displayed in the status bar.

Toolbar buttons functions are as follows:

-  confirm entered values and closes the window
-  change scale of the graph
-  change step and appearance of auxiliary grid
-  delete the points

You can delete entered points by clicking with mouse right button as well.

For radial bearings of liquid friction you should choose additionally what kind of oil supply will be used: to working zone or to non-working zone, to do this use radio buttons of the *Oil supply to..* group.

Calculation command

Calculation command initiates bearing calculation. It becomes enabled after you enter all the initial data. During calculation progress bar is displayed that shows current calculation percentage.

Results command

Results command displays *Results* dialog box (see fig.2.11). The command become enabled after calculation performing.

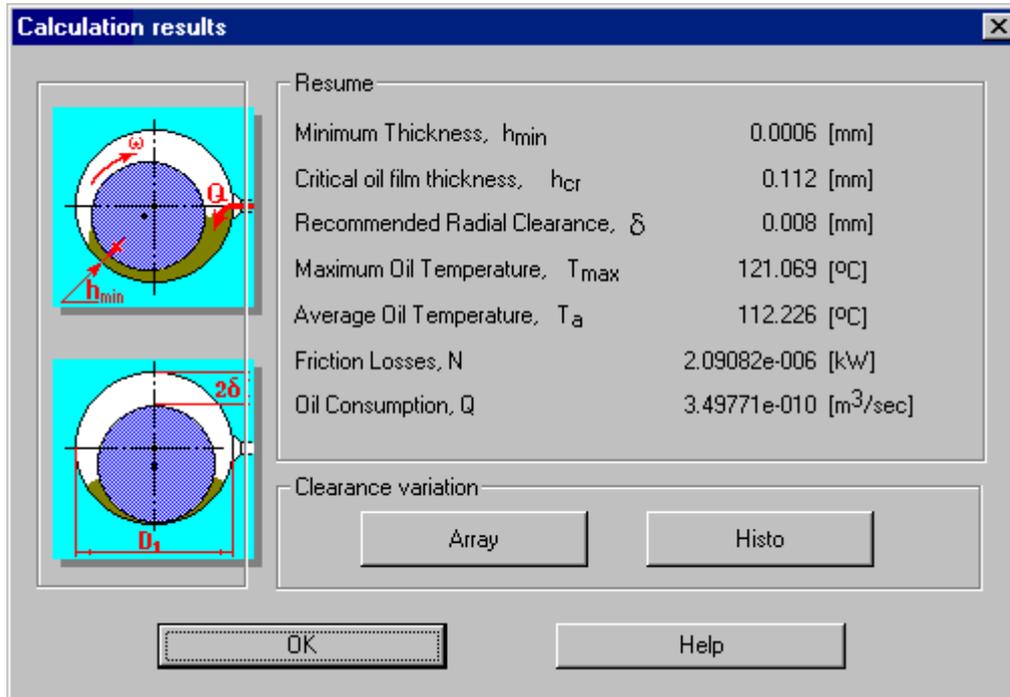


Fig. 2.11 The Results dialog box

Help menu

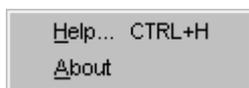


Fig. 2.12 The Help popup menu

Contents command

Help | Contents command invokes on the screen **APM Plain** help contents.

About... command

Help | About... command displays *About* dialog box. It contains information about program and licence holder.

