Getting started

UM Experiments

This manual leads you through basics of describing, running and analyzing the scanning projects using the Universal Mechanism software

2024

Contents

Getting Started: UM Experiments

This manual leads you through basics of describing, running and analyzing the scanning projects using the Universal Mechanism software. It assumes that you studied the gs UM.pdf[1]chapter, which is devoted to general concepts of simulation using Universal Mechanism, and you know how to fulfill simple operations: create new model, add graphical objects, bodies and joints, generate and compile equations of motion.

Three examples of using the scanning projects are considered. The first one is devoted to free and forced oscillations. The second one is devoted to scanning the railway vehicle dynamics (see gs UM Loco.pdf[2]). The example of using service of distributed calculations is shown in the last section.

The program tool for parametric scanning is available within **UM Experiments** module. To check if the module is in your UM configuration run **UM Input** or **UM Simulation** program, point to the **Help | About…** menu command. The **About** window appears. You can see the list of the supported modules in the **Configuration** section.

[1] www.universalmechanism.com/download/90/eng/gs_um.pdf
[2] www.universalmechanism.com/download/90/eng/gs_um_loco.pdf

1. Preface

It is often required in engineering practice to carry out series of numerical experiments, for example to analyze dynamical behavior and sensitivity of mechanical system or to find out optimal parameters of a system. The built-in **UM Experiments** module includes a scanning tool for advanced analysis of dynamics of mechanical systems.

Scanning projects automate fulfillment of series of numerical experiments, record course of experiments and save results of experiments on a hard disk for posterior analysis. Thus, the designer is released from monotonous execution of series of numerical experiments "manually" what saves working hours and prevents errors, which people unfortunately incline to do. In other words, the researcher defines the plan of experiments for scanning. Then the project is started and executed automatically. Current process statistics is available during the execution: number of experiments done, time left. Series of numerical experiments are resistant to shut-down of power supply. In that case all results are saved on a hard disk and results of the latter experiments are only lost.

There is a possibility to plot a time history of any saved performance of dynamical behavior of the considered UM model. Moreover, the designer can plot so-called summary graphs and surfaces. Scanning projects have no limitation of number of parameters. In other words, it is multi-parametrical.

Dimensions of projects are set by the designer so as to solve the specify problem. But on the other hand the designer has to take into account calculating efforts that are necessary for the project. Every tool has its own merits and demerits. However they all give the designer possibilities to solve quite many problems devoted to optimization of mechanical systems.

2. Scanning project

Describing, running and analyzing a scanning project for an oscillating system is discussed in this section. The process of creating the model is shown in details in the gs UM.pdf[3] manual.

Firstly, make sure that the model of the oscillating system is in your computer: create the model according the gs UM.pdf manual or check it in the {UM Data}\SAMPLES\TUTORIAL\oscillator directory or download it using the following link www.universalmechanism.com/download/90/oscillator.zip, see Figure 2.1.

More detailed information is in the **Part 6** of the UM User's Manual, see {UM Data}\MANUAL\06_UM_Experiments.pdf or

www.universalmechanism.com/download/90/eng/06_um_experiments.pdf.

Completely prepared scanning project, which is considered in this section, is available in the {UM Data}\SAMPLES\TUTORIAL\scan2 or on the Internet:

www.universalmechanism.com/download/90/scan2.zip.

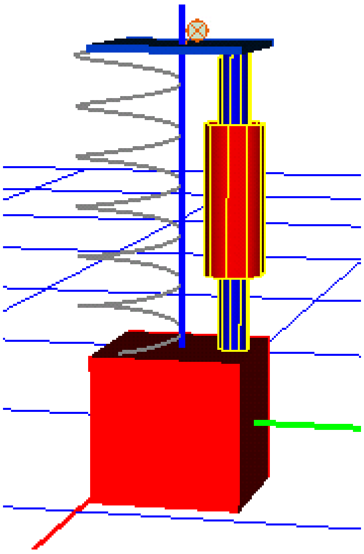


Figure 2.1. Oscillating system

[3] The gs_um.pdf file you can find in the {UM Data}\MANUAL directory or download using the following link: www.universalmechanism.com/download/90/eng/gs_um.pdf

2.1. Description of scanning project

Here we consider the example of scanning project for oscillating system. We will scan the dynamical property of the system depending on damping coefficient for free oscillation and frequency of exciting force for forced oscillation.

2.1.1. Creating new project

1. Run the **UM Simulation** program.
2. To create a new project from the **Scanning** menu select **New project**.
3. Input the full path to the scanning project, including project name, see Figure 2.2.
4. Click the **Create** button and after that a window for the description of new scanning project will appear, see Figure 2.3.

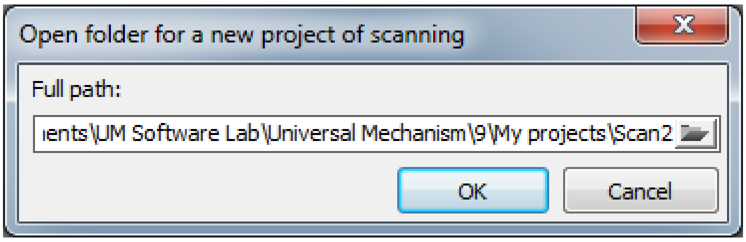


Figure 2.2. New project dialog

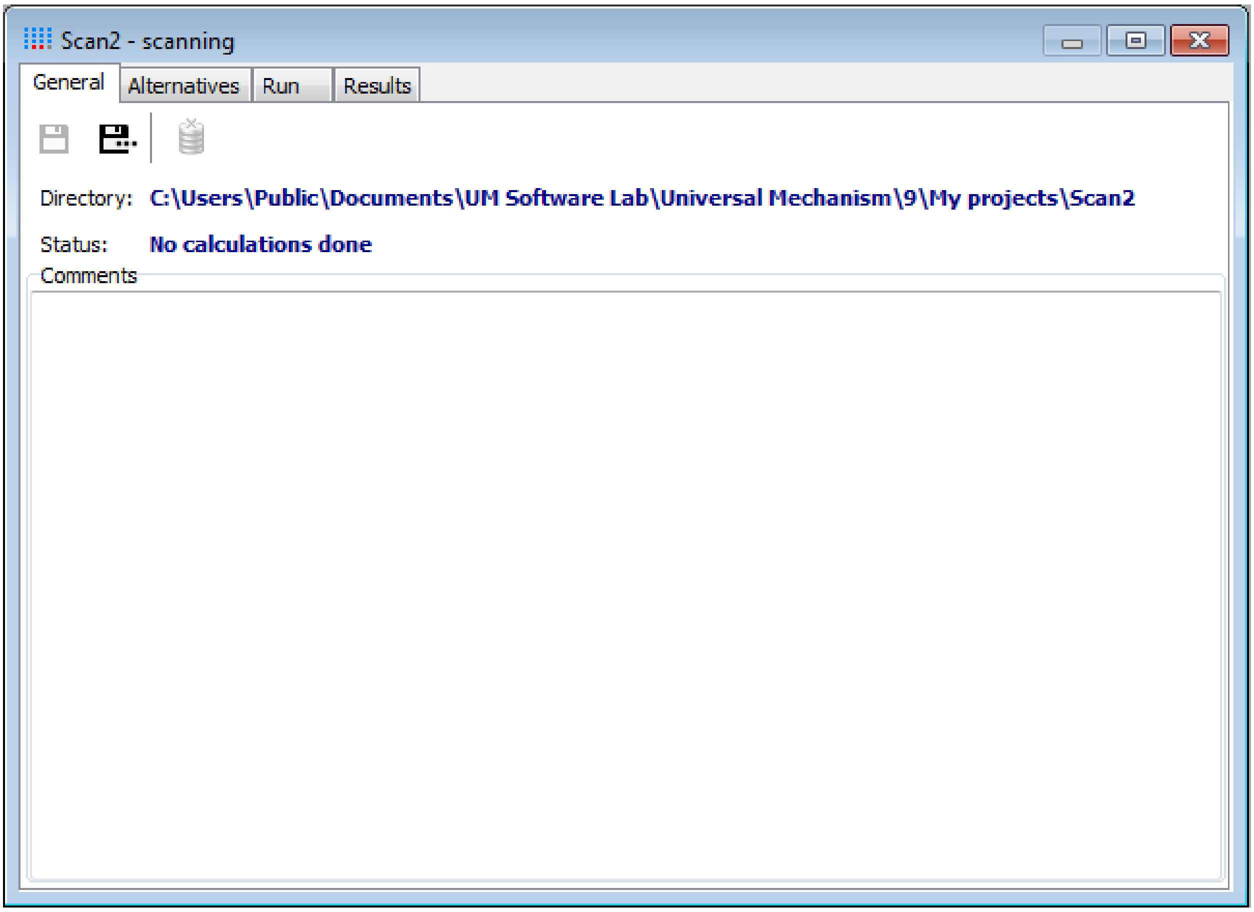


Figure 2.3. Scanning project: in the beginning

2.1.2. Loading a model

1. Select the **Alternatives** tab.
2. Click the **+** button (Add family of alternatives).
3. Select the **oscillator** model in the open dialog.

You can find the model in the {UM Data}\SAMPLES\TUTORIAL\oscillator or download via the following link: www.universalmechanism.com/download/90/eng/oscillator.zip.

Then the **oscillator** model is loaded and added to the **Family of alternatives** list (see Figure 2.4).

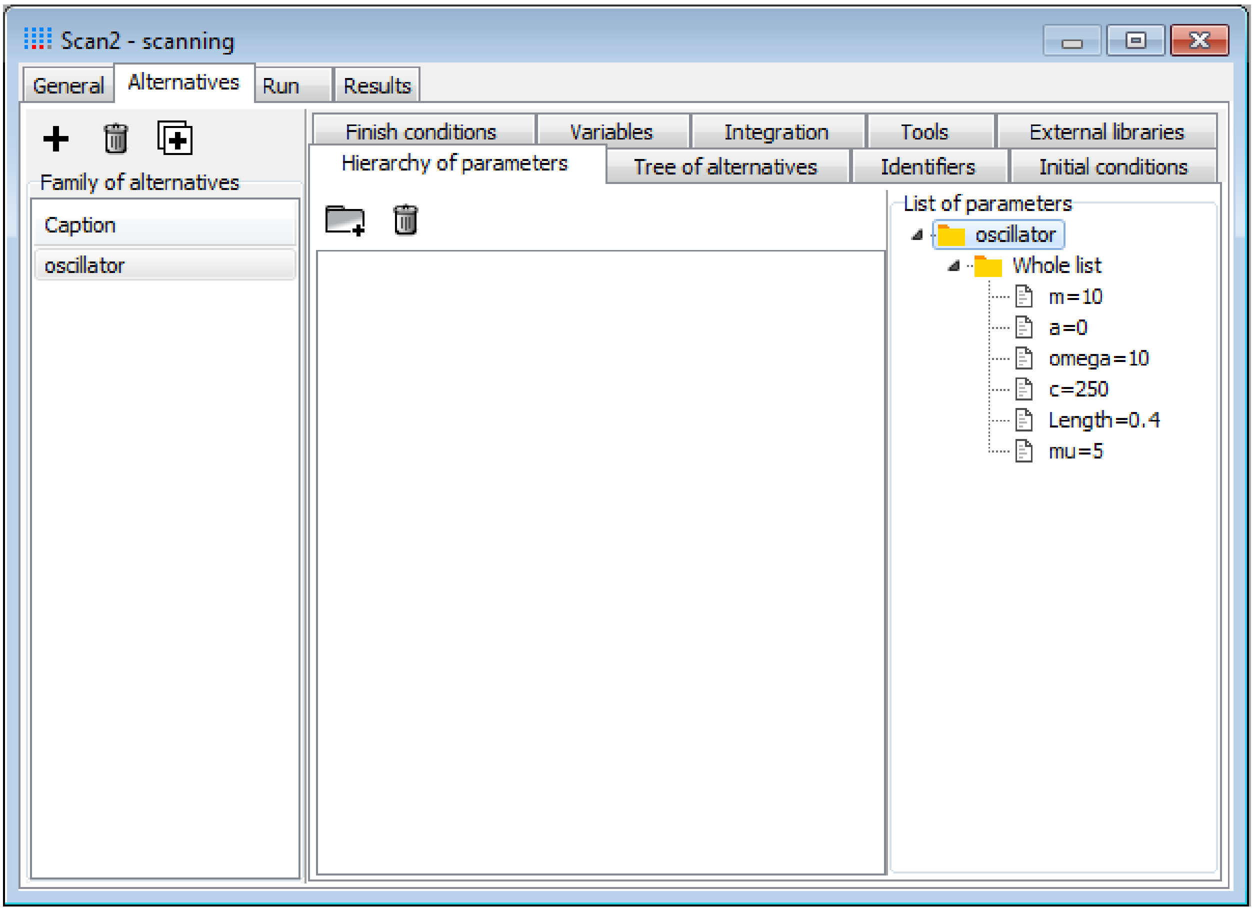
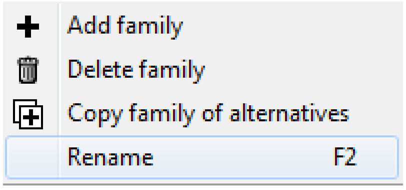


Figure 2.4. Adding new model

2.1.3. Renaming family of alternatives

Now we will rename the first family of alternatives.

1. In the **Family of alternatives** list select the first family and from the context menu select **Rename** or press **F2** key.



2. Set the name for the family to **Free vibrations**.

2.1.4. Hierarchy of parameters

Two cases are considered here: free and forced oscillations.

The first model (family of alternatives) is devoted to free oscillation analysis. The influence of the damping coefficient on the damped oscillation process is of interest.

1. In the **List of parameters** (in the right part of the form, see Figure 2.4) click the **mu** (damping coefficient) parameter.
2. **Changing parameter values** window appears. Add values {**0, 10, 20, 30, … , 100**}, 11 values total, see Figure 2.5.
3. Click the **OK** button and come back to the project window. The **mu** appears in the new **Group 1** in the **Hierarchy of parameters** tab, see Figure 2.6.
4. Select the **Group 1** node and click right mouse button to show the correspondent context menu. Select **Rename group of parameters** menu item and input **mu** as a group name. After this your scanning project should look like Figure 2.6.

So we describe eleven numerical experiments in this family of alternatives. Common settings for all of the experiments we will describe below.

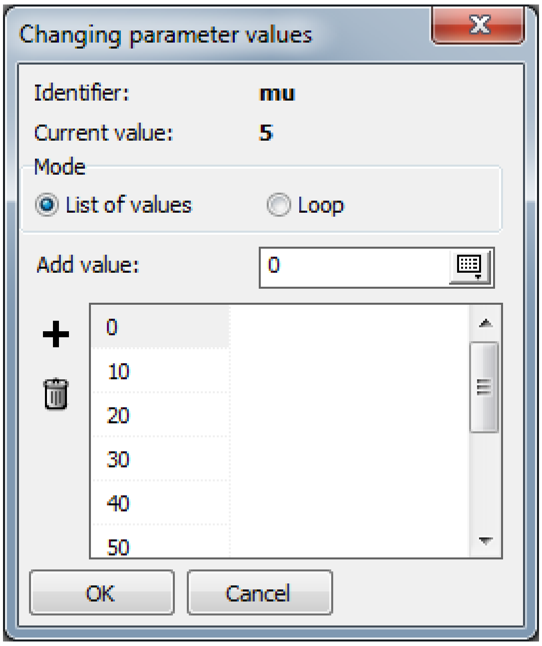


Figure 2.5. Changing parameter values

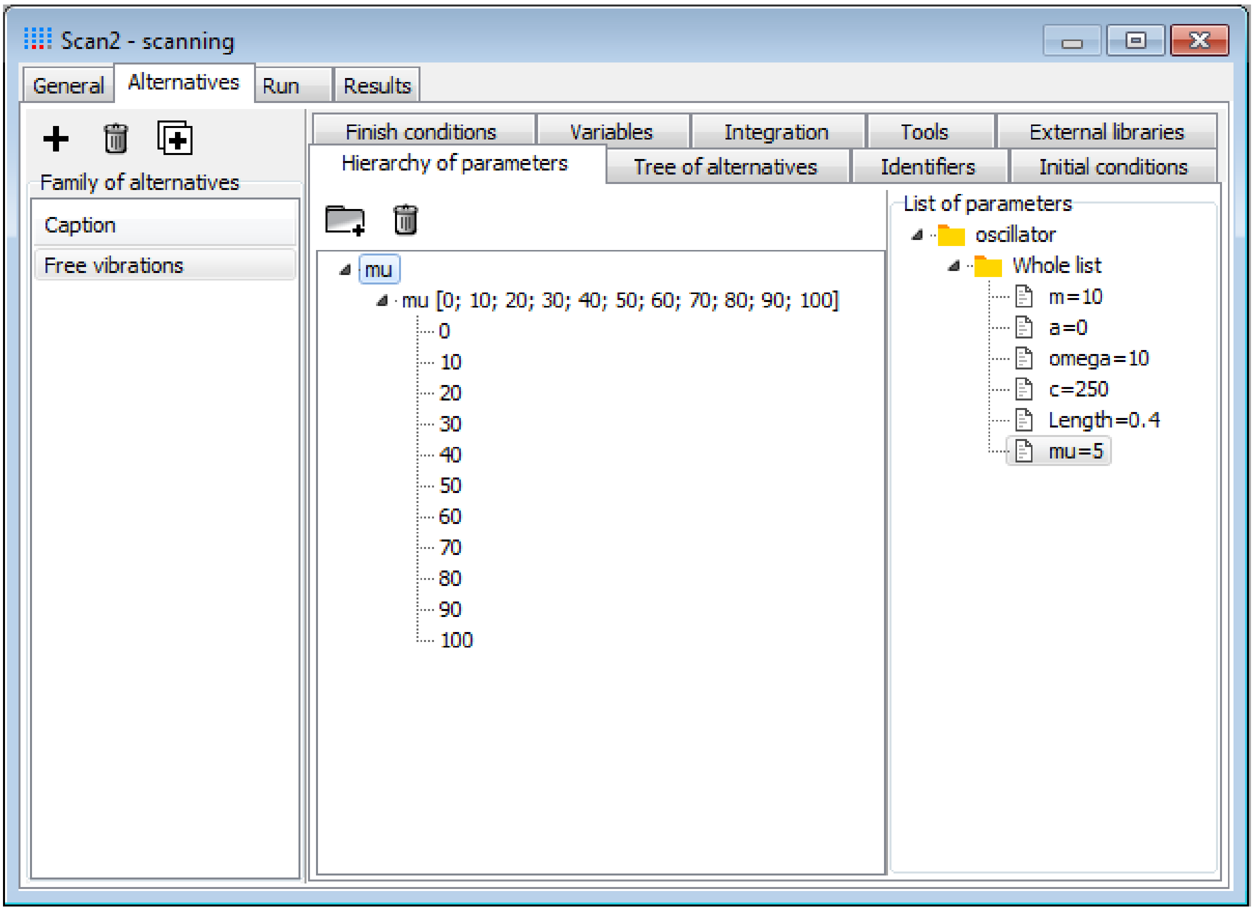


Figure 2.6. Hierarchy of parameters

2.1.5. Parameters of the model

In order to model the case of free vibrations it is necessary to fix the **Top** body – set the **a** parameter to zero.

1. Select the **Identifiers** tab.
2. Set **a** to **0.**

2.1.6. Initial conditions

1. Select the **Initial conditions** tab.
2. Set the **Coordinate | 1.1** to **0.1**, see Figure 2.7.

Position of the **Brick** at zero coordinates is quite close to a steady state position. We shift the **Brick** in order to increase the amplitude of oscillation.

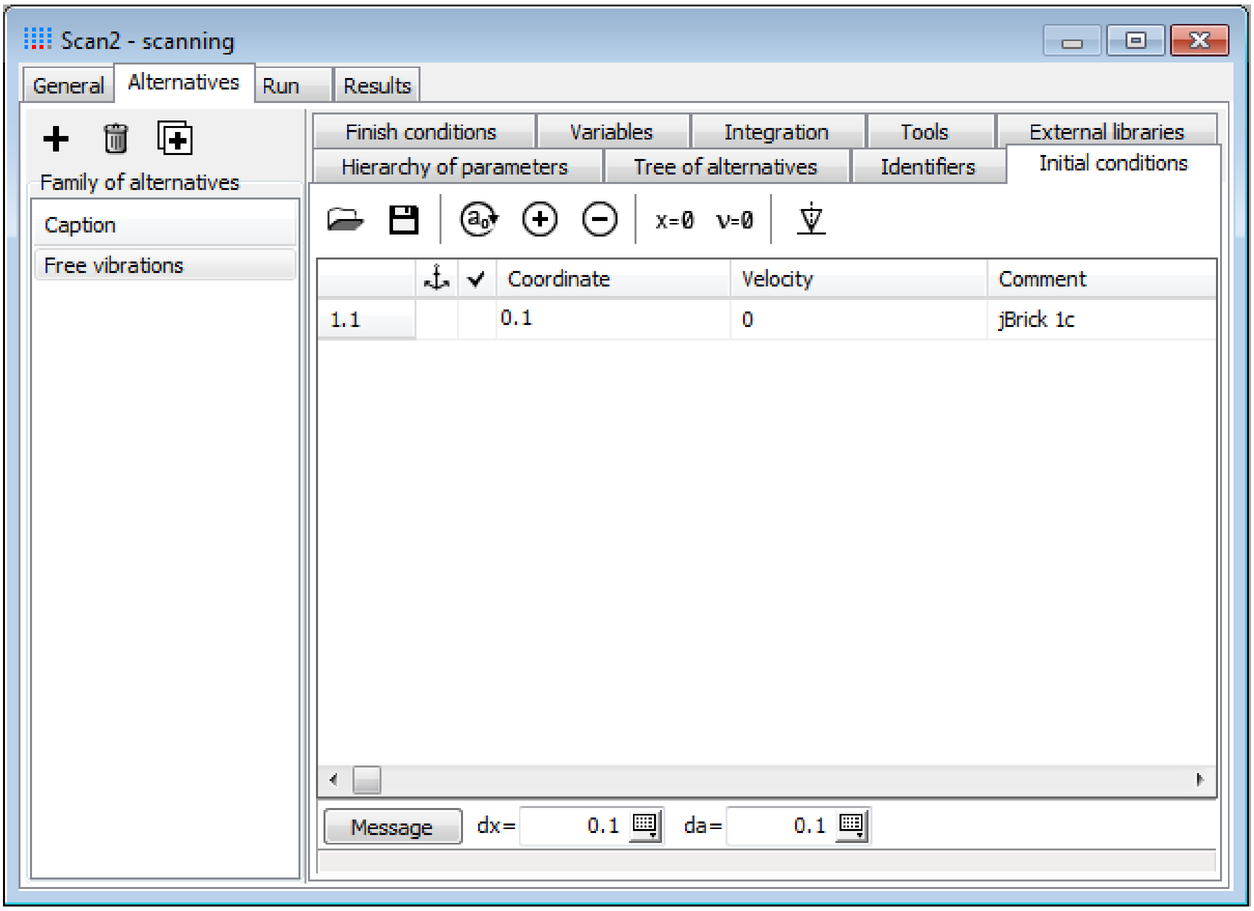


Figure 2.7. Initial conditions

2.1.7. Finish conditions

Here you can describe finish conditions for each numerical experiment in the current family (see Figure 2.8). Finish conditions are formulated in the following way: “Interrupt a numerical experiment if at least one of the conditions is satisfied”. Using scanning project you can set finish condition as

Variable [Condition] Numerical value.

You can use any variable from the **Wizard of variables** as a stop criterion. By default the following finish condition is formulated:

Time >= 10 seconds.

It means every numerical experiment finishes when 10 seconds of simulation time expire.

1. Set simulation time to **25** seconds, see Figure 2.8.

Note. You can set any variable as a criterion for finish conditions. Use just need to create a variable in the **Wizard of variables** and then drag it to the variable box (now you can see Time in that box).

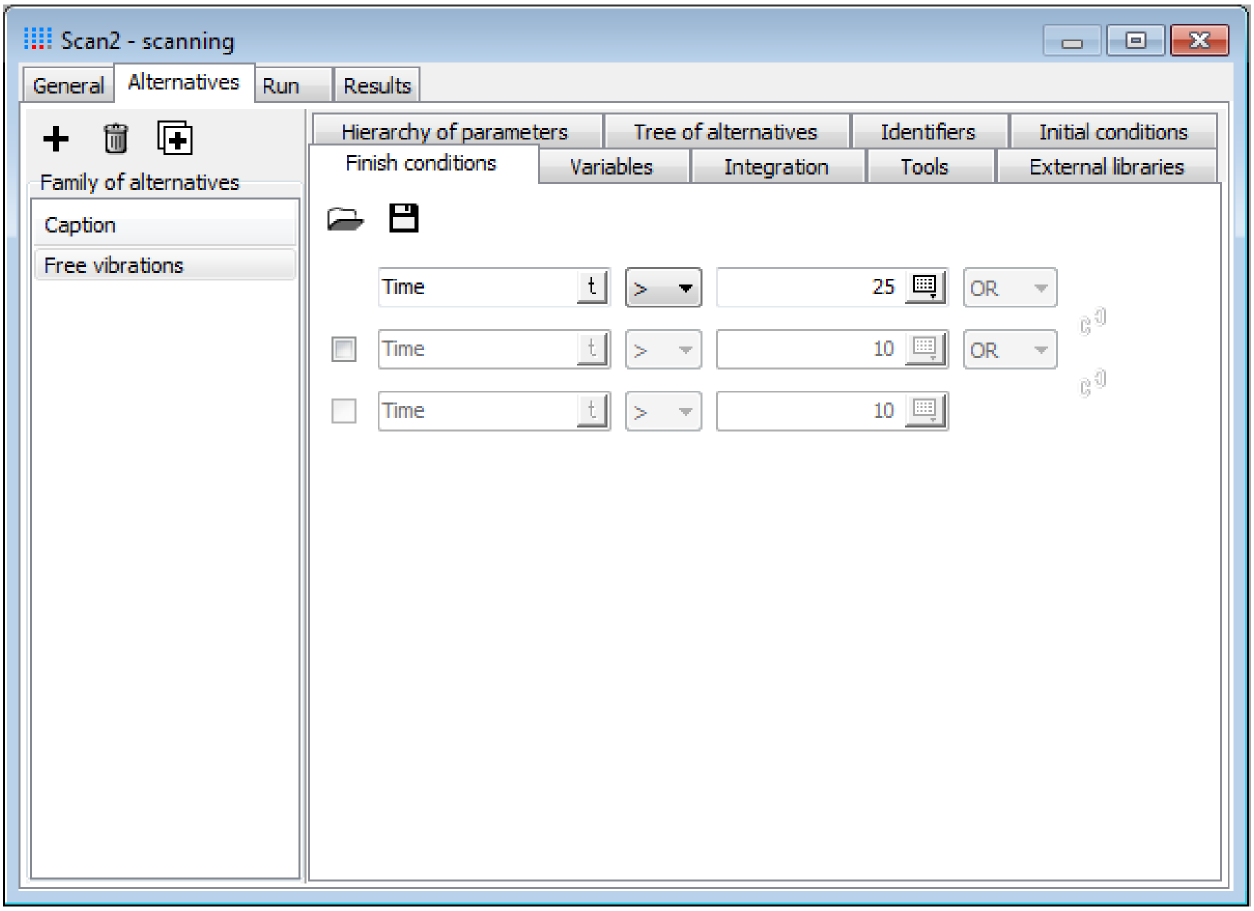


Figure 2.8. Finish conditions

2.1.8. Variables to save

1. Select the **Variables** tab.

Here you can see the **List of variables**, which will be saved for the each numerical experiment. In general you need to fill this list of variables with those variables you will analyze after the project fulfils.

2. Using the  button rename the **No name** tab to **Position**.

Now we will create the new variable – vertical position of the **Brick** – and drag it to this tab.

3. Open the **Wizard of variables (Tools | Wizard of variables…).**
4. Point to the **Linear variables** tab, select the **Brick** in the list of bodies on the left, set **Component** to **Z**.

5. Click the  to create new variable and then drag it to the **Position** tab.
6. Close the **Wizard of variables**.

After all your list of variables should look like in Figure 2.9. We described the family of alternatives for the case of free vibrations and now come to the case of forced oscillation.

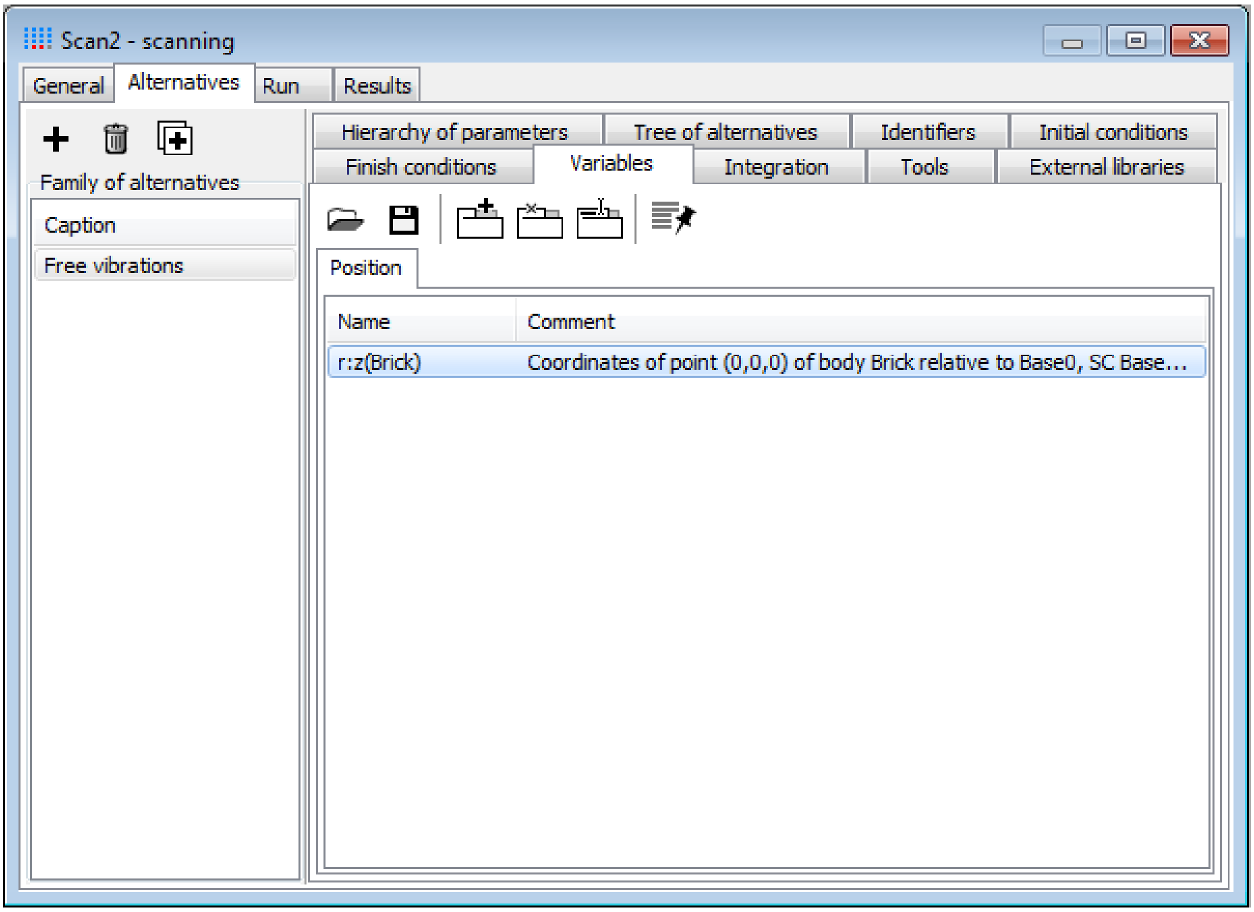


Figure 2.9. Variables to save

2.1.9. Forced oscillation

Now we will copy the first family of alternatives, set the damping coefficient to zero and then scan the dynamics of the system depending on the frequency of the exciting force. There will be the resonance case when the natural frequency of the system and the frequency of the exciting force coincide.

Copying the family of alternatives

1. In the **Family of alternatives** list select the **Free vibration** and from the context menu select the **Duplicate family of alternatives**. The second family of alternatives **Free vibrations (1)** appears in the list.
2. Select the second family and rename it to **Resonance**.

Hierarchy of parameters

3. Point to the **Hierarchy of parameters** tab (the **Resonance** family).

4. Select the **mu** group of parameters and from the context menu select **Delete group of parameters**, see Figure 2.10.

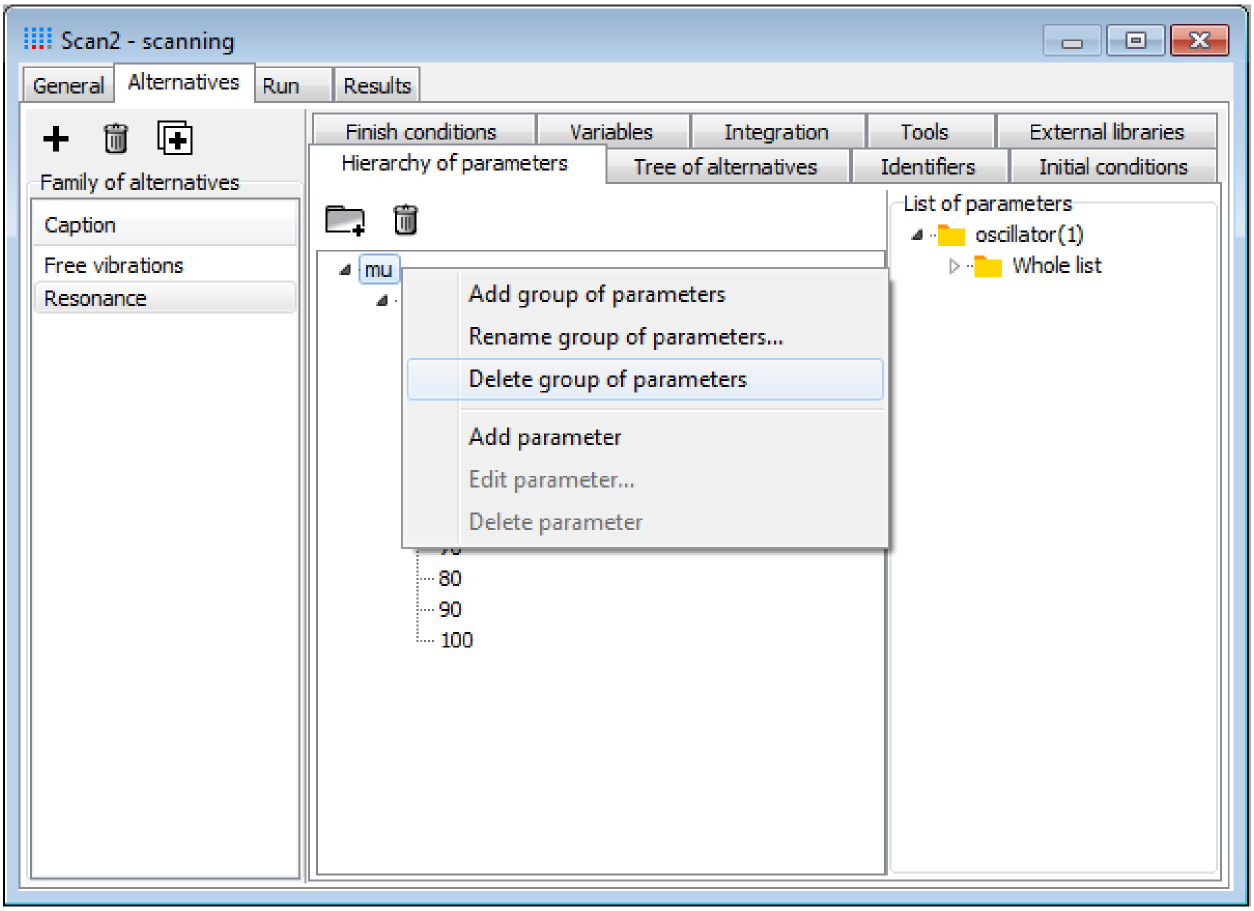


Figure 2.10. Deleting the group of parameters

5. Confirm the deleting the group of parameters.
6. Click on the **omega** parameter in the **List of parameters**. The **Changing parameter values** window appears, see Figure 2.11.
7. Set the **Mode** to **Loop**, set the rest parameters as it is shown in the Figure 2.11. Press **OK**. We just described 16 iterations, from 0 up to 15 rad/s.
8. Rename parameter group to **omega**.

Hierarchy of parameters for the **Resonance** family now should look like it is shown in the Figure 2.12.

Parameters of the model

9. Select the **Identifiers** tab.
10. Set **a = 0.05** and **mu = 0**.

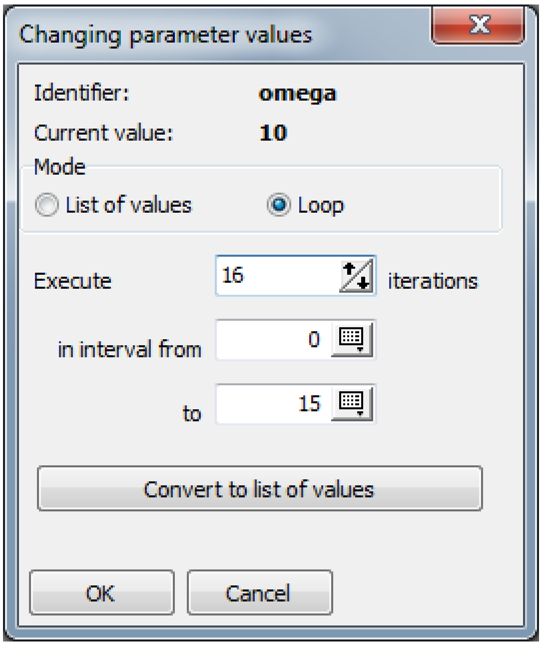


Figure 2.11. Frequency of the exciting force

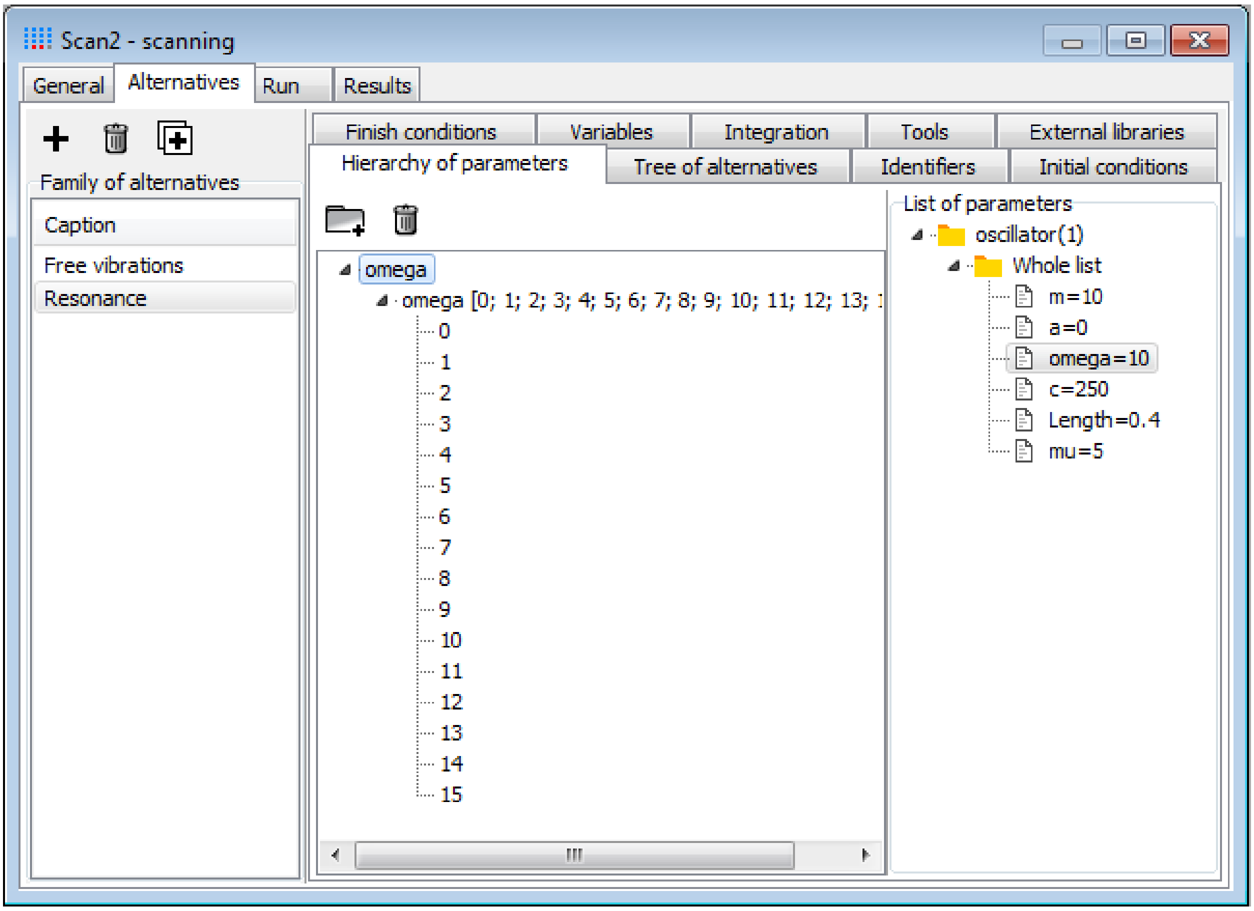


Figure 2.12. Hierarchy of parameters for the Resonance family

2.2. Running the project

1. Select the **Run** tab.
2. If you did everything in order then the **Report** contains the «**Error not found**», see Figure 2.13.

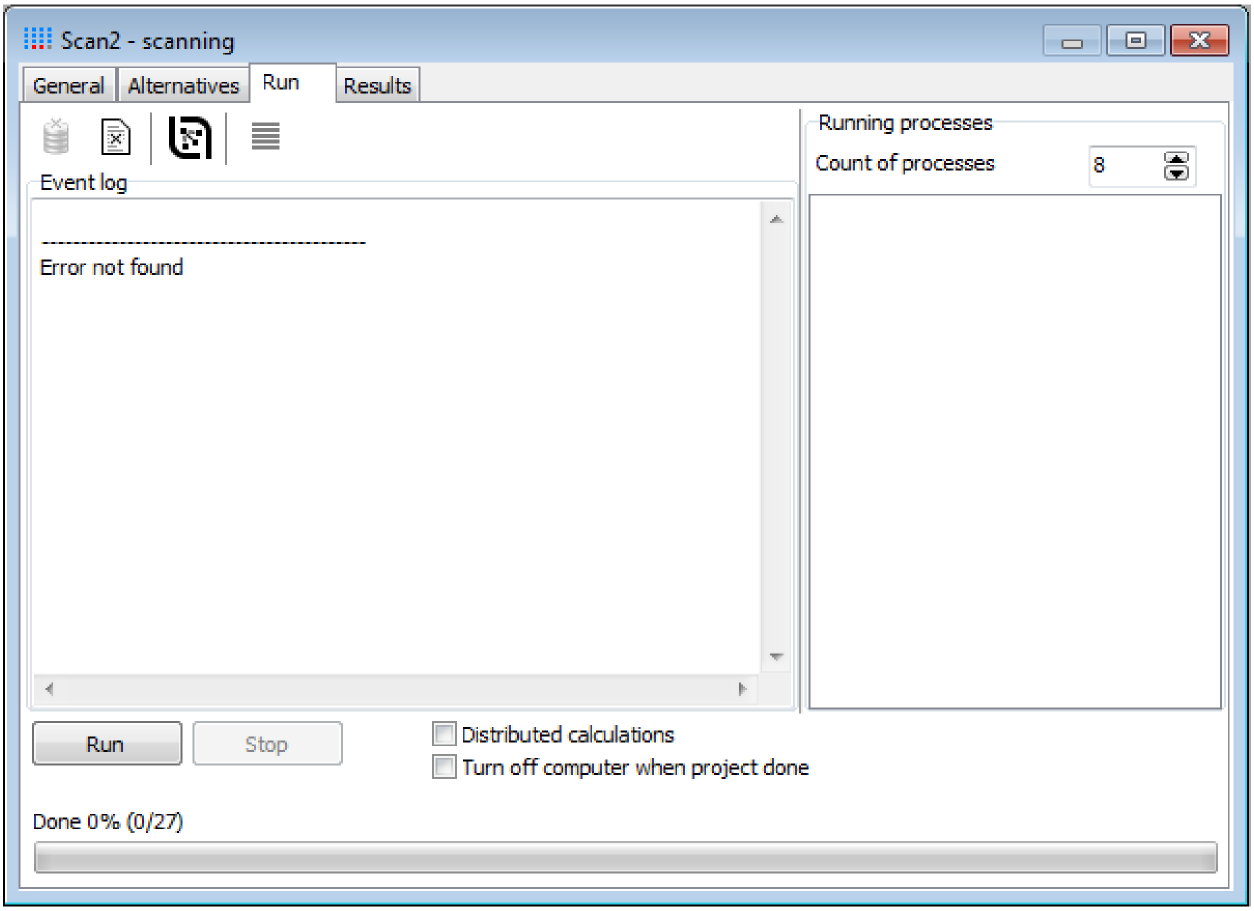


Figure 2.13. Running the scanning project

3. Click the **Run** button.

Fulfillment of the numerical experiments starts. The **Event log** shows identifier values and time efforts for every experiment, see Figure 2.14.

The model is quite simple and it takes about a second for every numerical experiment.

4. You can see the **"Calculation of project of scanning is over"** message after project fulfillment.

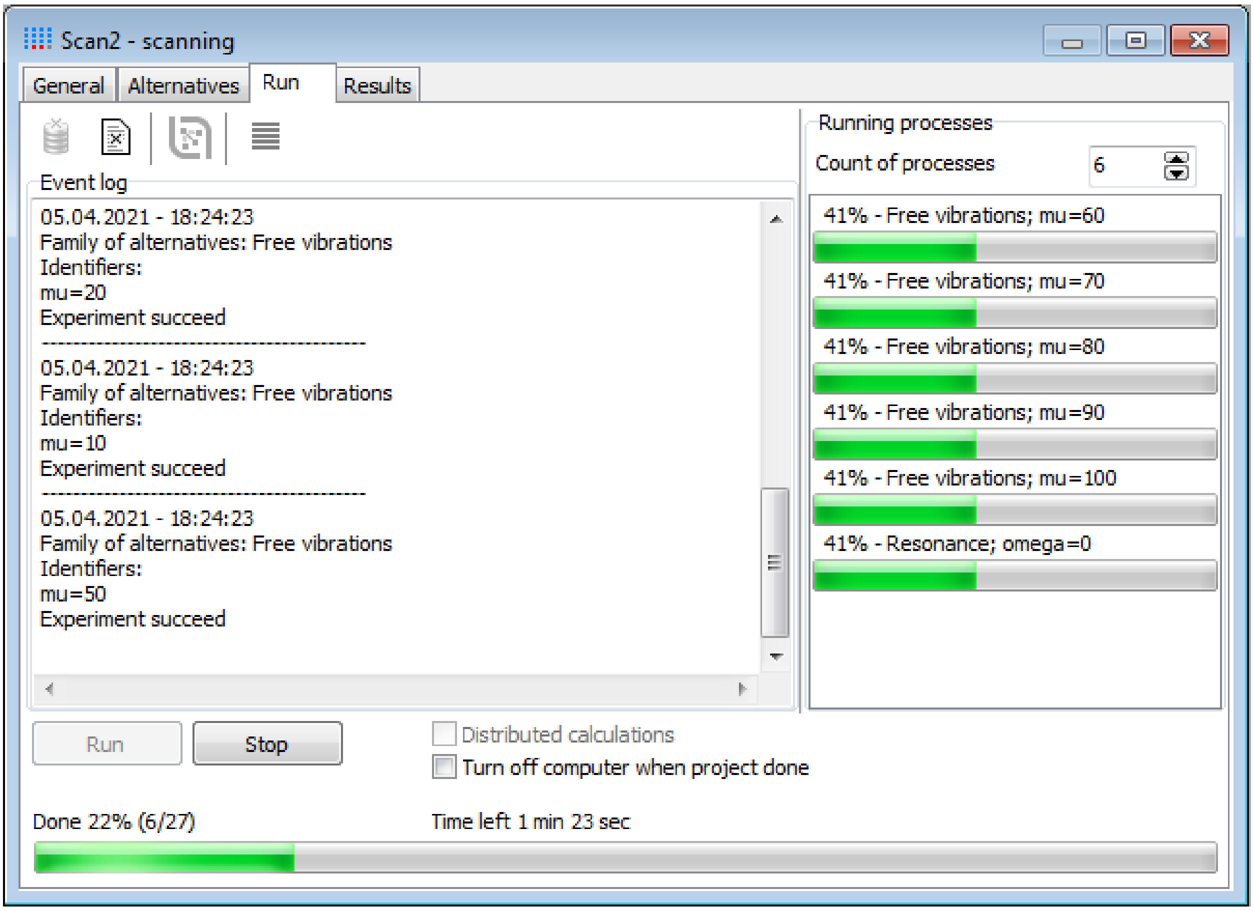


Figure 2.14. Running the project

Maximum simultaneously running processes is limited by the count of core in your processor (for example, Intel® i5 has 4 cores; Intel® i7 has 8 cores). By default **Count of processes** is set to the maximum available cores. You can decrease it to keep some CPU resources for some other applications, background processes or services.

2.3. Analyzing obtained results

2.3.1. Results of separate experiments

All numerical experiments are done now and we come to its analysis.

Free oscillation

1. Select the **Results | Free vibrations** tab, see in Figure 2.15.

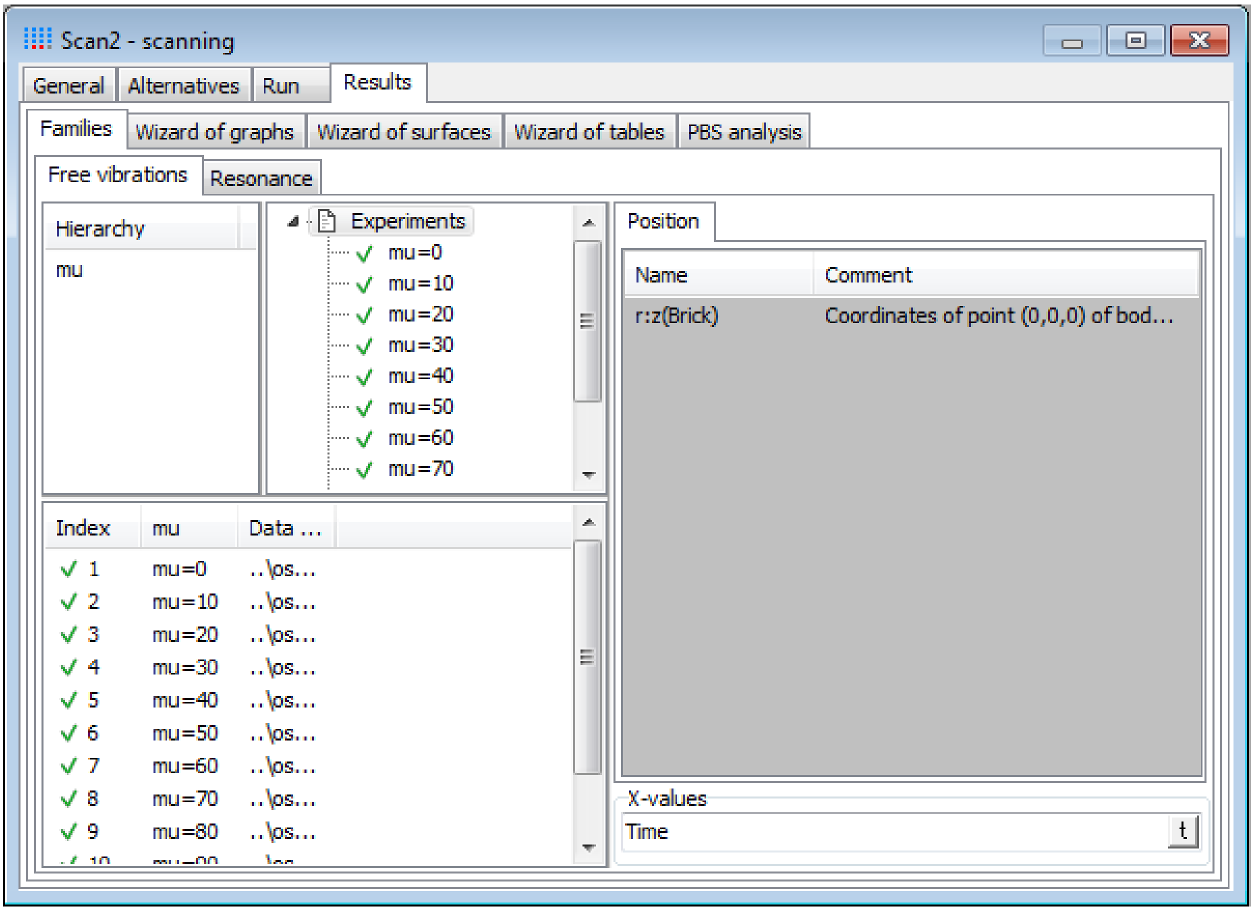


Figure 2.15. Results of the project

Let us compare the plots of the vertical position of the **Brick** at different values of damping coefficient.

2. Open new graphical window **(Tools | Graphical window…).**
3. Select the project window and select all experiments in the left bottom side of the window (**Free vibrations** family), see Figure 2.16. To select all experiments you can use the **Select all** context menu command or mouse + Shift or Ctrl keys.

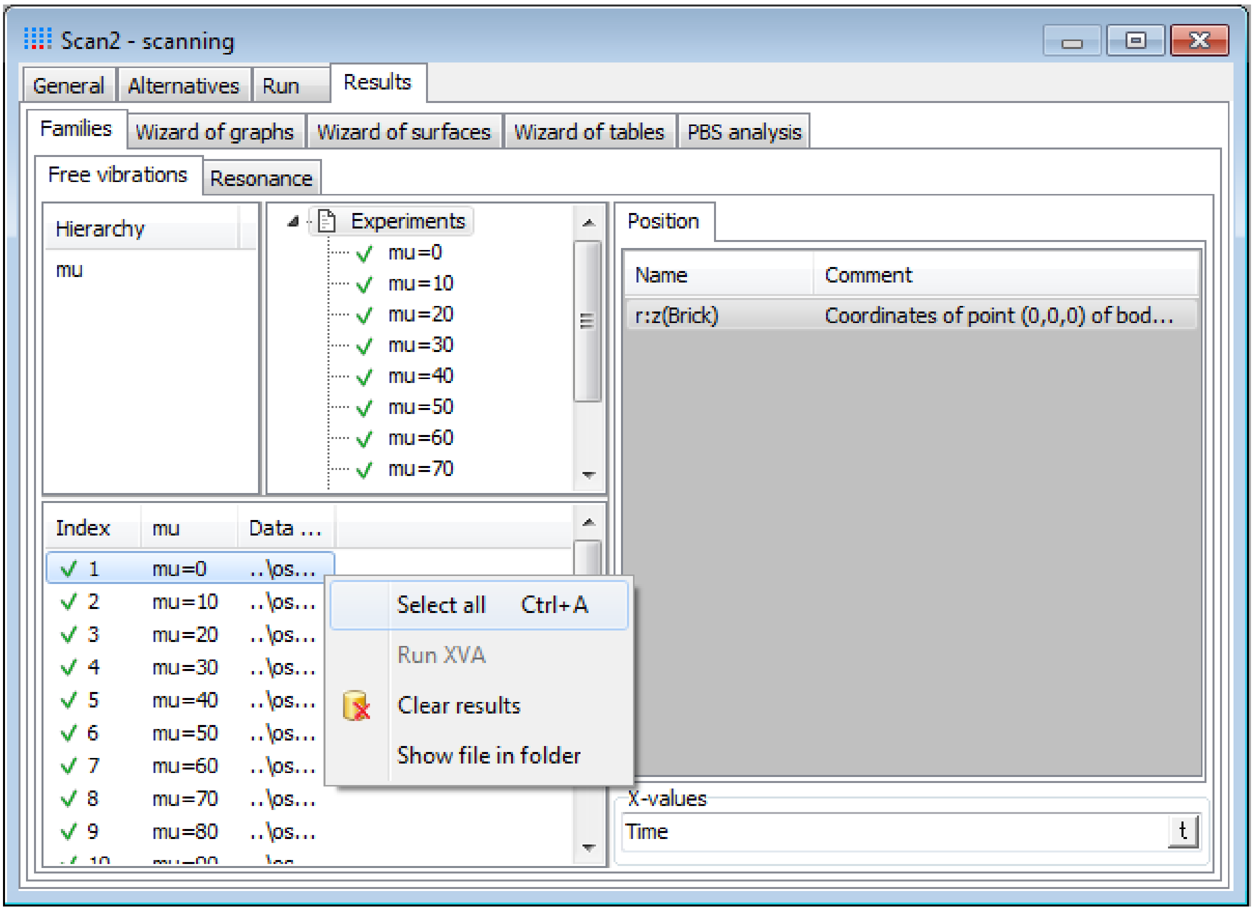


Figure 2.16. Results of the project: select all experiments

4. In the list of variables (the **Position** tab) select the **r:z(Brick)** variables and drag it to the graphical window. Plots of vertical position of the **Brick** are shown in the graphical window, see Figure 2.17.

Note. You can show plots of calculated variables in graphical windows as well as analyze them in the **Table processor** and **Statistics** window (see the **Tools** menu).

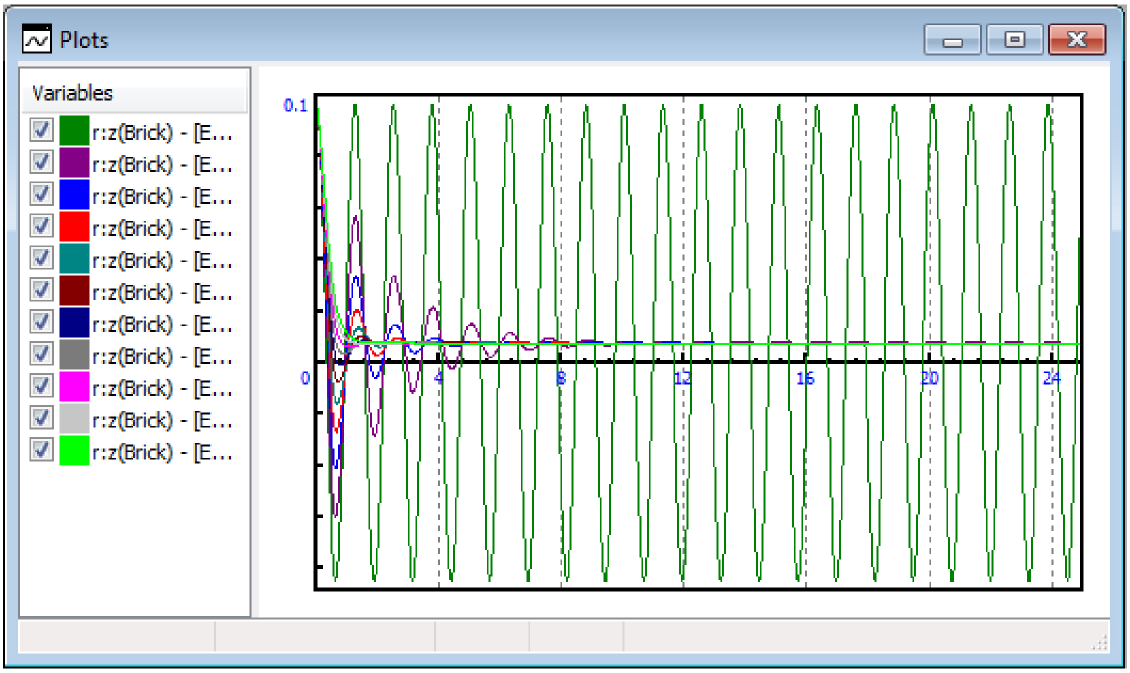


Figure 2.17. Vertical oscillation of the brick at various damping coefficient

Forced oscillation

Now we come to the analysis of the case of forced oscillation.

1. Open new graphical window.
2. Point to the scanning project window and select the **Results | Resonance** tab.
3. Select all experiments and then drag the **r:z(Brick)** variable to the graphical window, see Figure 2.18. The resonance case is clearly seen there.

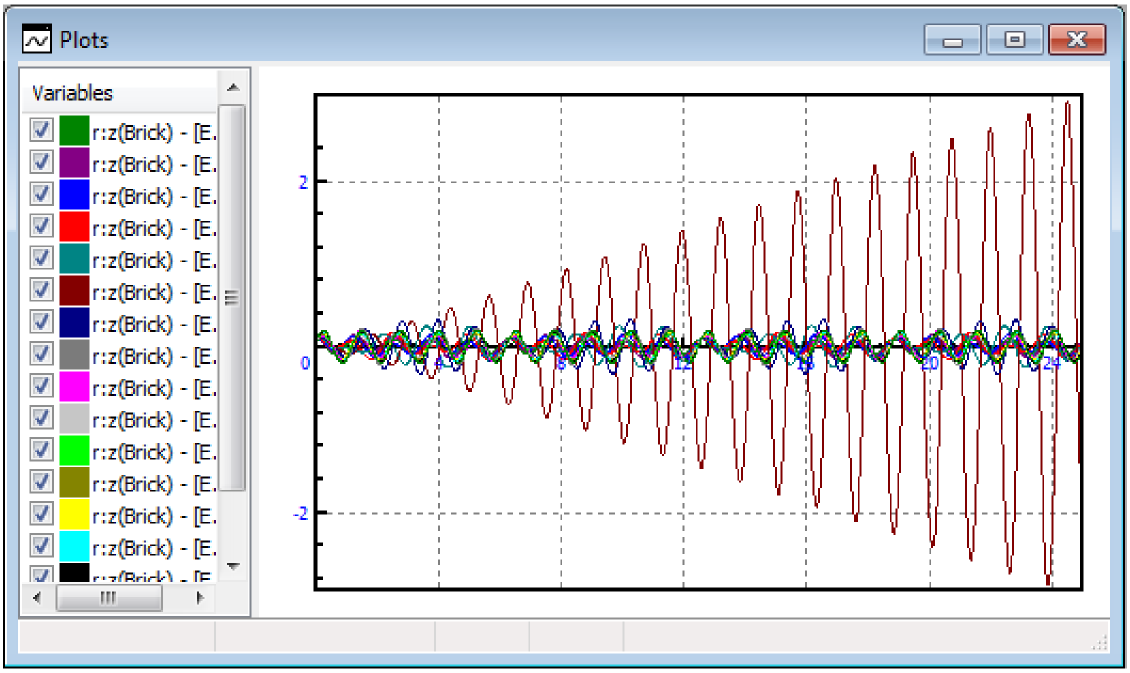


Figure 2.18. Forced oscillation

2.3.2. Summary graphs

There are several tools, which give you a possibility to get an overview of dynamics of a system without analyzing separate plots of every experiment. Here we mean wizards of graphs, surfaces and tables.

Let us create the graph of the *standard deviation* (Std_Dev) of the vertical oscillation depending on frequency of the exciting force.

1. Select the **Results | Wizard of graphs** tab.
2. In the **Family** list select **Resonance**.
3. In the list of variables select **r:z(Brick)**.
4. Set **Functional** to **Std_Dev** (Standard Deviation).
5. In **Parameter** combo box select **omega**.
6. Click the a_{+} button on the top panel of the **Wizard of graphs**.

Summary graph is shown in the graphical field, see Figure 2.19. Its analysis shows that the maximal standard deviation corresponds to **omega = 5 rad/s**. The reader, which is familiar with vibration theory, certainly notices that plot in the Figure 2.19 is very similar to amplitude-frequency characteristic.

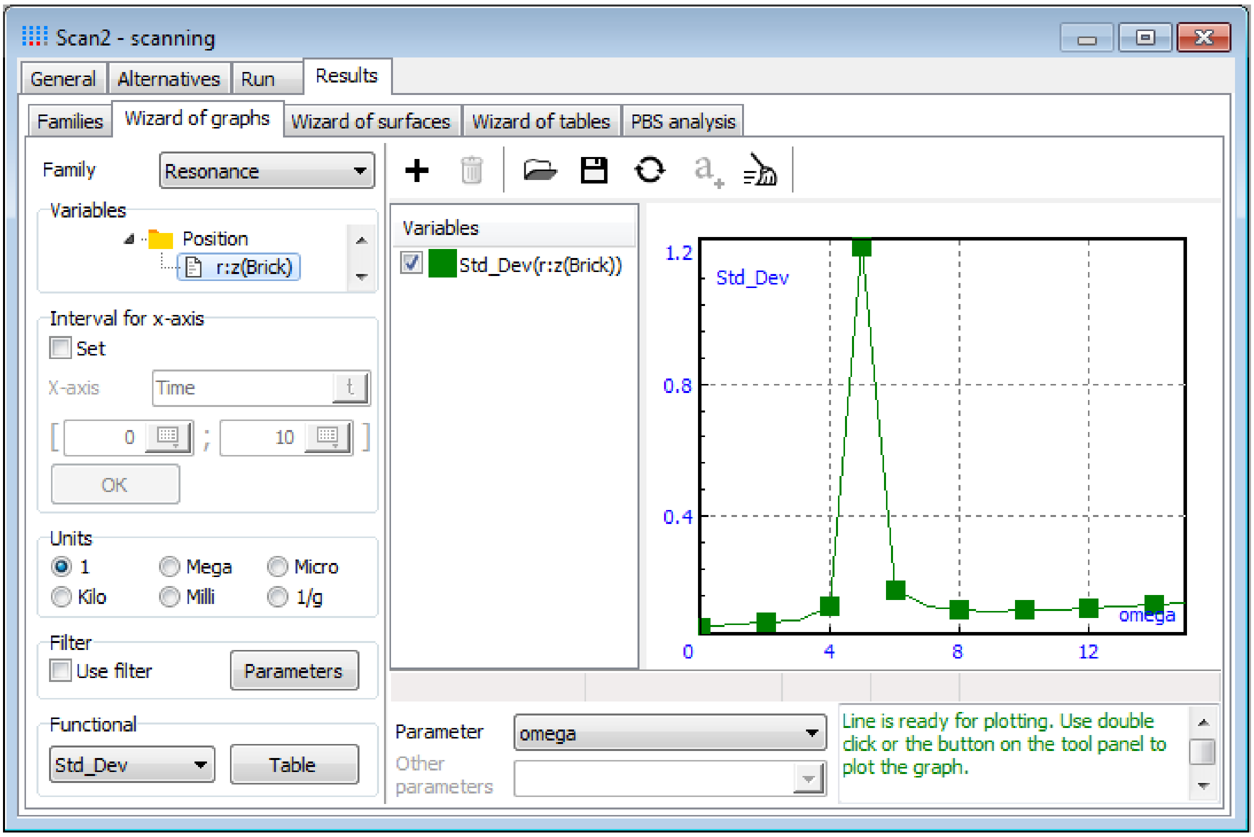


Figure 2.19. Wizard of graphs. Abscissa: frequency of the exciting force. Ordinate: standard deviation of vertical oscillation of the **Brick** body.

3. Scanning: implementation to railway vehicle dynamics

Creating, running and analyzing scanning projects in the field of railway vehicle dynamics are considered in the gs UM Loco.pdf file of UM User's Manual. Example of determining the critical velocity of AC4 railcar is shown.

That manual you can find in the {UM Data}\MANUAL directory or download using the following link: www.universalmechanism.com/download/90/eng/gs_um_loco.pdf.

4. Scanning: using UM Cluster tool

UM Cluster tool is the extension of the **UM Experiment** module that allows you to perform distributed calculations of scanning projects on computers in your local network. Calculating a project in parallel can provide significant overall time savings and significantly improve the efficiency of your network environment. This tool is used for executing time-consuming projects by sharing the load between computers in your network.

This tool is very suitable to use within computing centers, laboratories, R&D or simulation departments. Server of distributed calculations is based on using TCP/IP that allows employing any computer not only in local network, but also in Intra- and Internet for the needs of your project.

UM Cluster consists of two parts: client and server. The client part contains all the software components necessary for calculations and does not require a complete Universal Mechanism to be installed on every client computer.

Running scanning projects with the help of the **UM Cluster** is considered in the 23 um cluster.pdf[4].

[4] http://www.universalmechanism.com/download/90/eng/gs_um_cluster.pdf