

Motor Sizing Tool

Startup Guide

R88D-1SN[]-ECT (1S-series)
R88D-1SAN[]-ECT (1S-series with safety functionality)
R88D-KN[]-ECT(-R) (G5-series)
R88D-KN[]-ECT-L (G5-series)
R88D-KN[]-ML2 (G5-series)
R88D-KT (G5-series)
R88D-GN[]-ML2 (G-series)
R88D-GT (G-series)
R7D-BP (SmartStep 2)

A blue rectangular graphic with a gradient from light blue at the top to dark blue at the bottom. The text "Startup Guide" is centered in white, with "Startup" on the top line and "Guide" on the bottom line.

Startup
Guide

Motor Sizing Tool Version 1.70

Operation Manual



January, 2023
Omron Corporation

Copyright

Motor Sizing Tool v1.70

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1. Overview

The Motor Sizing Tool (MST) helps to select the appropriate motor and drive from the mechanical structure in which the motor is to be used, and from the operating patterns, mass, reduction ratio and other properties of the various components required to calculate inertia and torque. Various functions have been incorporated into this program to make it easier to select an OMRON motor and drive to aid in producing higher quality systems in response to this demand from the customers.

OMRON Motors and Drives model data are contained in a database, making it possible to select the optimum motor without having to input data.

This manual describes the operating procedures of the Motor Sizing Tool.

2. New features from 1.60 to 1.70

At the latest version has been added the following new features:

- **CAM tables can be embedded in the project**
 - A dedicated check-box in the Profile editor within CAM instruction allows to embedded data from a previous loaded CAM profile.
- **Modification in Braking resistor calculation**
 - New check-box in Tools/Settings/Configuration for enabling selection in the calculations of Omron's or third parties' resistors.
 - Corrected calculation for only considering braking resistor once maximum drive's voltage is achieved.
 - New criteria based on pulse energy affordable by the used resistor.
- **Change on splash screen name from Mechatronics Sizing Tool to Motor Sizing Tool**
- **Improvement on singular points in Crank element**
- **Generation of plain text file (.txt) for opening projects in between different region**
 - In case of detecting a motor, drive or accessory none selectable from a loaded axis it is suggested to save lost data before opening the corresponding axis.
 - The saving process is launched once per axis when user tries to open it.
 - Data saved concerns to motor, drive and accessories.
- **Added name of the project in between brackets for the sake of clarity**
- **New template for print report**
- **Increase the maximum supply voltage setting range by region**
 - Indicated rated range without brackets
 - Extended range in between square brackets
 - New warning in case of using a voltage value out of rated values but within extended range. Warning appears by means of a red asterisk at left of axis in Project explorer list. A new property in Axis Property Grid labelled as *Status drive's voltage* will detail if there is some consideration on the voltage selection.
- **Added the default value of motor safety margin and Length for new blank projects**
 - Two new entries on Tools/Settings/Configuration allows to configure the default safety margin percentage and default length for blank new projects.
- **Added new mechanical element: Eccentric load with gravity consideration**
- **New pre-defined axis regarding Cart and Eccentric load with gravity consideration**
- **Added new density imperial units**

- New possible selection entries for density in Tools/Settings/Units includes Lb/in³ and lb/ft³.

- **Bug fixed and minor changes**

- Predefined or user-created Lite project/axis update of values after saving and re-opening the same project/axis.
- Warning advise for Dynamic brake detailing stop calculation does not include the external forces.
- Updates on Omron's database.
- Correction of wheel inertia consideration for projects with a Cart item.
- Solved crash and errors after closing or saving an axis containing a winder/unwinder.
- Missing labels on Trapezoidal Advanced instruction on Lite projects.
- Show one decimal value in case of external resistor needed in Application results/results tab.
- Sorting on the print report of the items contained in an axis by connection order from left to write instead of by inserting order.
- New order of graphs in the print report.

3. Installation

This section explains how to install the program. To the correct installation of the product, the destination computer must accomplish the following requirements:

- Operating systems accepted (32/64 bits):
 - Windows 10
 - Windows 8
 - Windows 7
- Software installed requirements:
 - Microsoft .NET Framework 4.0 Full package
 - Microsoft .NET Framework 4.5 Full package
- Available disk memory (at least 50 Mbytes is recommended).

To have the sufficient privileges to complete the installation for all users of the machine, the installer file must be executed as Administrator. The easiest way is by right-clicking the file and then clicking Run as Administrator to start the installer.

1- Execute the Motor Sizing Tool installer file. When the opening message appears, read the warnings and then click the Next button. To end the installation operation, click the Cancel Button.

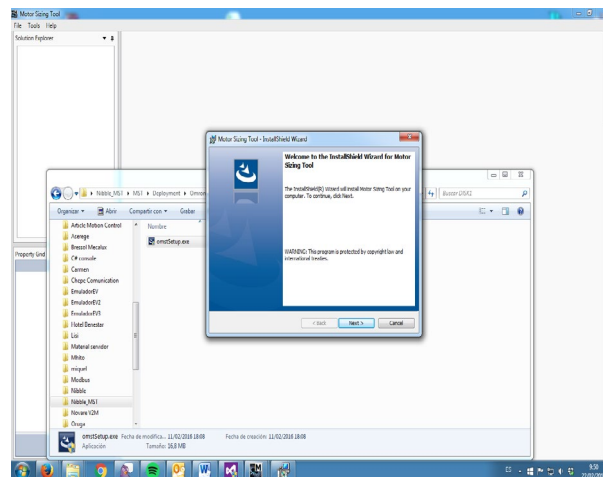


Fig. 1 Installation Wizard. Step 1.

2- Define the installation directory. To change the directory, click the Change button. After checking the installation directory, click the Next button to continue.

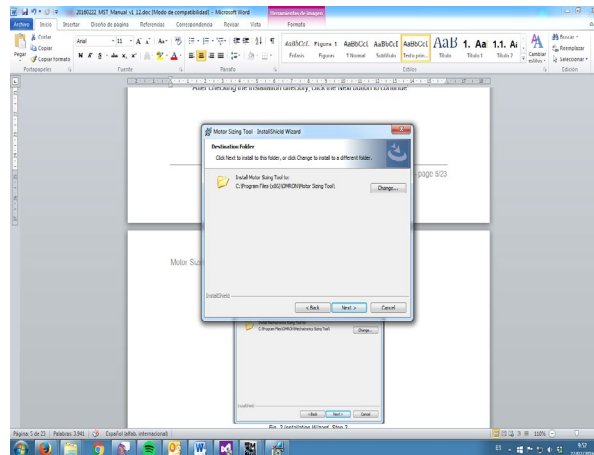


Fig. 2 Installation Wizard. Step 2.

3- Recheck all the information for copying the program files. If anything needs to be changed, click the Back button. If no changes are required, click the Install button to continue.

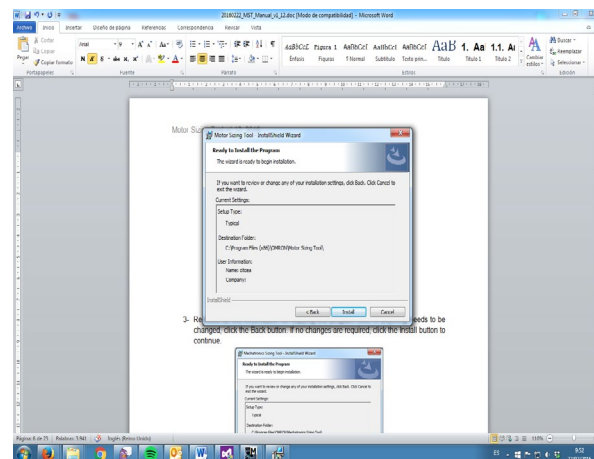


Fig. 3 Installation Wizard. Step 3.

4- When the installation is successfully completed, next message appears.

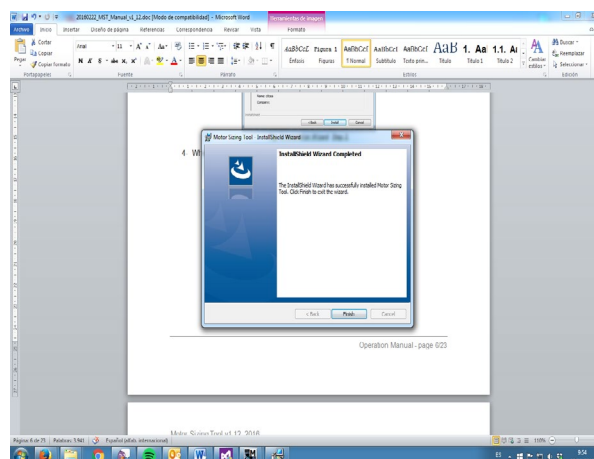


Fig. 4 Installation Wizard. Step 4.

4. Creating a new project

Once user initially executes the application, appears the splash screen and after that, the tool starts-up. The aim of the splash screen is to inform the user that the software is loading. See Fig. 5.



Fig. 5 Start-up Window

4.1. Wizard Window

After the user starts the application, no project is loaded and a popup wizard window is shown to guide the user with a set of steps that must be completed in a sequential order. The conceptual appearance of this window is:

- List of the steps, where the current step is highlighted. The steps still to be edited are unmarked.
- 'Next' and 'Back' buttons allow navigating within the wizard project steps.
- 'Finish' button closes the window and goes to main screen with a default project configuration.
- 'Cancel' button closes the window and goes to main screen with no project opened.

The wizard process consists, firstly, on a welcome step and different followings steps according to which type of project wants to be created -Lite or Full-.

- **Welcome Step:** asks for 'New Lite project', 'New Full project' or 'Open project'. See Fig. 6.

- *New Lite project:* will follow the wizard in order to build a Lite project. A Lite project is a project in which the axis chains contained in a machine are protected in terms of components (not possible to modify predefined axis) but some fields are editable. Lite projects presents the following details:

- Can only Create "Lite projects"
- Can only open "Lite projects".
- Can only save opened projects as "lite project"

- **New Full project:** will follow the wizard in order to build a Lite project. A Full project is a project in which the axis chains in which the axis chains contained in a machine are fully editable in terms of components and fields. Full projects presents the following details:
 - Can only create “Full projects”.
 - Can open “Lite projects” and “Full projects”.
 - Can only save opened projects as “full project”
- **Open project:** allows select an existing project (*.omst.xml) and, after that, the tool will go to main screen with the project opened.

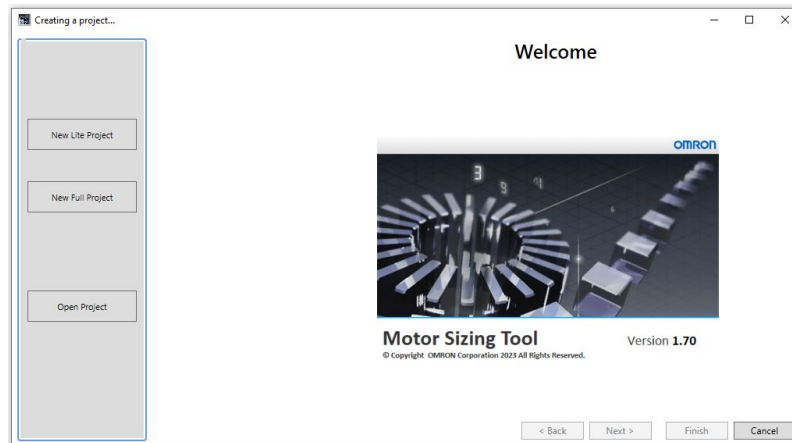


Fig. 6 Welcome Window

- **Project information Step:** request of project, author and customer information. The project name must be specified, but even if the other information is not set, it will not affect the operation of the application. See Fig. 7.
- Main project data: name, date, comment.
- Author data: name, department, mail.
- Customer data: name, identifier, company, mail, phone, address.

Fig. 7 Project information Window

Author data persists after to reinitialize a new project.

- **Machine information Step:** request information of machine, device model and version of the controller and the type of power supply. An available list of controllers is

displayed. The generic model can be selected when a third-party controller is used. Each machine is associated to one controller. See Fig. 8. This step is by-passed for Lite projects.

- Machine data: name, number, picture.
- Controller: name, device model & version, power supply.

Fig. 8 Machine information Window

- **Axes information Step:** ask for the general configuration of the machine. The 'Predefined axes' must be inserted into the defined machine. See Fig. 9.

- A list of predefined axes is available.

Fig. 9 Axes information Window

After finish these steps, the configured project is built.

4.2. Main Window

After finishing the wizard process, the software goes to the main screen with the skeleton of the configured project and with the machine view as a background.

As a general view, the user interface of the application has the following control and function elements. By default, the windows are arranged in a similar structure shown in Fig. 10.

For Full projects two tool anchorable toolbars will be available at top right: Axis toolbox and Machine toolbox. In case of Lite projects, the Axis toolbox is not available and the Machine toolbox is always shown.

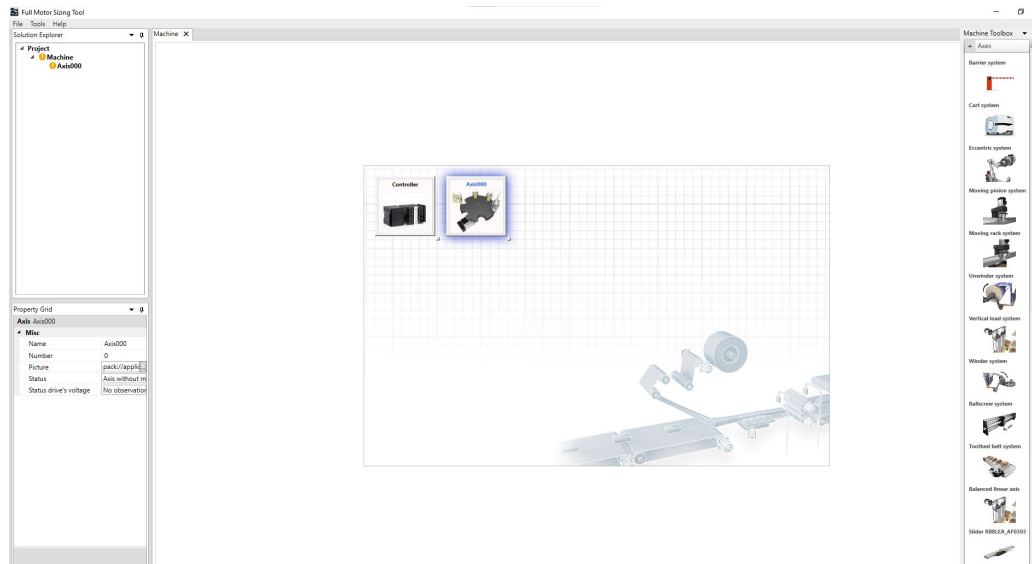


Fig. 10 Main window

It's possible to create customizable layouts. By clicking and dragging, the windows can be docked, undocked, floated, auto-hidden, or moved to new locations. Next Fig. 11 shows this functionality.

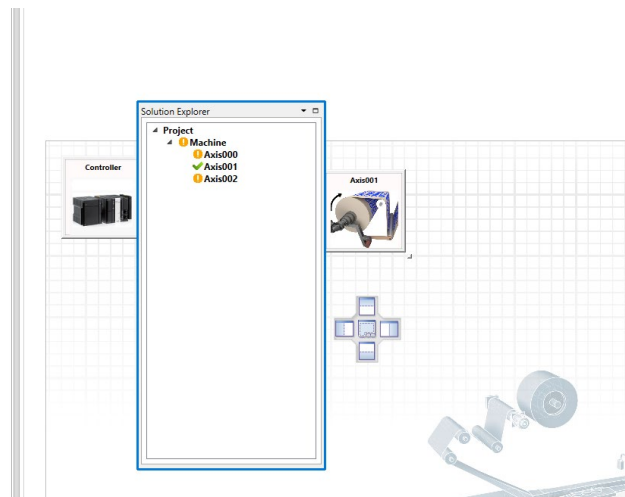


Fig. 11 Dockable windows

4.2.1. Toolbar

By clicking the items in the toolbar, which is partially shown in Fig. 12, the user can directly invoke the most frequently used functions. The toolbar is split in three tabs.

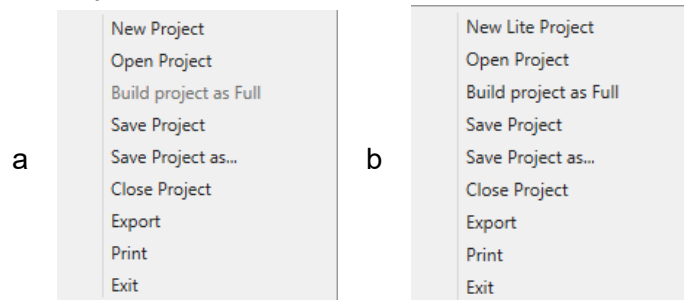


Fig. 12 Tool bar. a- For Full projects. b- For Lite projects

- **File tab:**

- New project/ New Lite project: by selecting this command, the project information template is opened, from which the following configuration steps of the wizard are continued in order to build the new project. The tool may consult whether save the current project or not before to close the current project.
- Open project: opening an existing project. The tool may consult whether save the current project or not before to close the current project. If the saved project was Full it is opened as Full. In case of being saved as Lite it is opened as Lite.
- Build project as Full (only available from Lite projects). In case of a created Lite project the user can build the same version in Full. The user will be asked sequentially to save the current Lite version and after its full version. After executing this command, the tool is relaunched to welcome step
- Save Project: the current project state is saved in a project file. If the file already exists, it is overwritten. The project remembers if it has been save as Full or Lite.
- Save Project as: save the project with the specified name and directory. The project remembers if it has been saved as Full or Lite.
- Close project: close the opened project. The tool may consult whether save the project or not before to close the current project.
- Export: by clicking this command, an XML file is created in order to create a Sysmac Studio template project.
- Print report: by clicking this command, the report configuration window is opened. Using this window, the user selects the information to be printed in the document viewer.
- Exit: closing the application. The tool may consult whether save the current project or not before to close the application.

- **Tools tab:**

- Settings: opens a dialog box, which contains the basic settings of the application. See Fig. 13. The first tab includes the measurement units shown in the tool. The second tab includes some configuration parameters;
 - Region of the accessories linked with the motor and drive selection (Europe, Japan, America, China, Taiwan, Southeast Asia/India/Pacific or Korea).
 - Step time and maximum number of points used in the dynamic brake stop functionality when its calculation is launched.
 - Embed images option allows to save images into the project file when is saved.

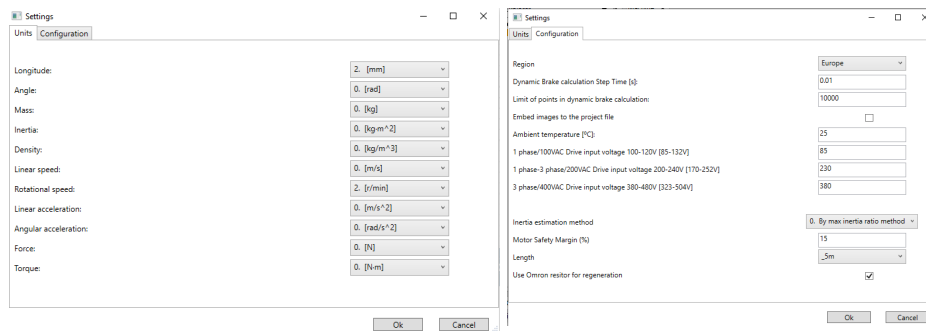


Fig. 13 Settings

- Select language: changes the language of the user interface. English, Spanish, French, Italian, German, Japanese, Korean, Chinese Simple and Chinese Traditional can be selected.
- Inertia estimation method: Two inertia criteria are available:
 - **0. By max inertia ratio method.** Same as in versions previous to MST v1.30. Verifies that the Load inertia reflected to the motor doesn't exceeds the maximum.
 - In the *Application results/Results tab*, on row concerning Inertia & Columns (3) and (4) it is shown **Max. Inertia Ratio** (data from motor) and **Inertia ratio** (ratio application reduced inertia to the motor over motor inertia), respectively.

	(1)	(2)	(3)	(4)
Max. Speed [r/min]	0.0	2000.0	0.00 %	
Max. Torque [N-m]	0.0	0.0	71.7	0.00 %
Effective Torque [N-m]	0.0	0.0	28.7	0.00 %
Inertia [kg-m ²]	0.0002	0.0051	10.0	0.04
Regenerative Energy [J]	0.0	0.0		
Power of Regeneration [W]	0.0	0.0		

Fig. 14 Application results/Results tab

- In the *Device Selection/Motor List* appears same information as previous point but showed in the Max. Inertia Ratio column and as tooltip once the cursor is on a specific motor.

Judgement	Model	Rated Speed (r/min)	Max. Speed (r/min)	Rated Torque (N-m)	Max. Torque (N-m)	Max. Inertia Ratio	Inertia (kg-m ²)
OK	R88M-K3K010T-B	1000	2000	28.7	71.7	10	49.2
OK	R88M-K3K010F/C-B	1000	2000	28.7	71.7	10	49.2
OK	R88M-K4K510C	1000	2000	43	107	10	49.2
OK	R88M-K4K510T	1000	>2000	43	107	10	49.2

Fig. 15 Device Selection/Motor List

- The Judgment criterion for this option is as follows

Judgment	Criterion
Green (OK)	Inertia ratio <= Max. Inertia Ratio
Orange (Not recommended)	Max. Inertia Ratio < Inertia ratio < 2*Max. Inertia Ratio
Red (NotGood)	Inertia ratio >= Max. Inertia Ratio

▪ **1. By intelligent method.** Based on stability (inertia stiffness) and energy criteria. This method involves two judgment criteria, one for each mentioned case. Values in Application results/Results tab and in Kinetic energy evaluation (Max. inertia for method 0) column at motor list provides different data in respect with method 0.

• In the *Application results/Results tab*, on row concerning Inertia & Columns (3) and (4) it is shown data for the stability case. The higher the stiffness of a mechanical element is, the bigger the max inertia ratio for good stability results. Thus, in column (3) it is shown the minimum for the mechanical elements of an axis (see following table, Column Max. inertia ratio for good stability), hereinafter named **StiffnessMinValue**. Although it is not shown, it is obtained the maximum value **StiffnessMaxValue** (see following table, Column Max. acceptable inertia ratio), too. In column (4) it is shown **Inertia Ratio**.

ELEMENT	MAX. INERTIA RATIO FOR GOOD STABILITY	MAX. ACCEPTABLE I NERTIA RATIO			
Linear-Rotary			Winder	50	500
Rack&Pinion	30	100	Cranck	25	60
Rotary-Linear			Rotary-Rotary		
CAM	25	60	Gearbox	100	200
Ballscrew	30	100	Gear	60	120
Nut Rotating	25	80	Timing Belt	40	80
Belt Conveyor	20	50	Cylinder block	100	150
Roll feed	30	60	Eccentric	100	150
Suspension	30	60	Block	100	150
Pinion&Rack	40	80	Linear-Linear		
Pinion&Rack (moving pinion)	25	60	Linear Mass	100	150
			Balancer	80	130
			Axis carrier	--	--
			Lever	40	80

- The judgment criterion for stability is shown in *Application results/Results tab* as follows

Judgment	Criterion
Green (OK)	Inertia ratio <= StiffnessMinValue
Orange (Not recommended)	StiffnessMinValue < Inertia ratio < StiffnessMaxValue
Red (NotGood)	Inertia ratio >= StiffnessMaxValue

- In the *Device Selection/Motor List* appears energy related data. In the Kinetic energy evaluation column appears the maximum absorbable energy from the motor viewpoint. This value is computed as $E_{k_max_motor} = \frac{1}{2} * J_{motor} * (1 + MaxJ_{ratio}) * W_{max_motor}^2$, where J_{motor} is the Motor inertia, $MaxJ_{ratio}$ is Max. Inertia Ratio and $W_{max_motor}^2$ is the maximum angular speed of the motor. As tooltip it is represented the ratio E_{k_max} over $E_{k_max_motor}$ in percentage. E_{k_max} represents the maximum energy to the drive and is computed as $E_{k_max} = \frac{1}{2} * J_{total} * W_{max_app}^2$, where J_{total} is the reduced axis inertia to the motor and $W_{max_app}^2$ is the maximum angular speed of the pre-defined profile. Note: Some special consideration is done for axis with winders/unwinders where it is computed the worst energy case (max speed or max energy during the movement).

- The judgment criterion for stability is shown in *Device Selection/Motor List* as follows

Judgment	Criterion
Green (OK)	$E_{k_max} \leq 0.9 * E_{k_max_motor}$

Orange (Not recommended)
Red (NotGood)

$$0.9 * E_{k_max_motor} < E_{k_max} < E_{k_max_motor}$$

$$E_{k_max} \geq E_{k_max_motor}$$

- **Help tab:**

- Help file: opens the manual / help file of the tool.
- About this program: opens a popup window showing the version number and some information about the application. See Fig. 16.

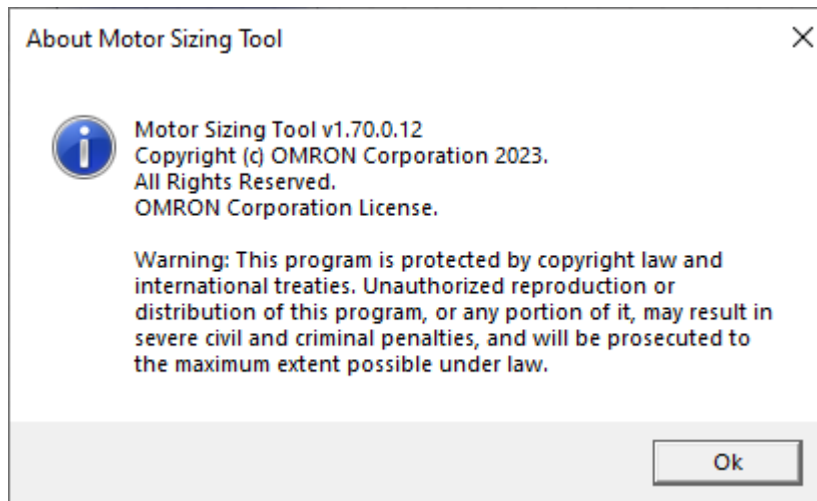


Fig. 16 About this program window

4.2.2. Solution Explorer

The project tree window, as an expandable tree view of the machine, classifies all the elements included into the current project, which are machines and axes.

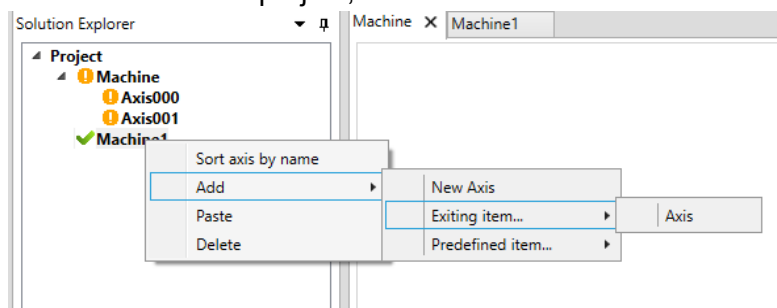


Fig. 17 Solution Explorer window

All the elements inserted in the project will be listed hierarchy, as the example shown in Fig. 17.

All items are selectable, so by left clicking, its information appears in the property grid window.

By double left clicking a machine or axis, the corresponding window is opened.

By right-clicking one item, a popup menu is opened. Depending of the item, the selecting commands are:

- **Project item:**

- Add Machine

- **Machine item:**

- Add:
 - New Axis: adds a new empty axis.
 - Existing item: allows adding a previously saved axis from a selectable file (*.axis.xml).
 - Predefined item: allows adding a predefined item.
- Paste: allows including a previously copied item inside the current machine.
- Delete

- **Axis item**

- Save as: allows saving the item in a file, which can be used into the same or another project.
- Copy: creates a duplication of this item, which can be pasted inside the same or another machine.
- Delete

Each item has a green/orange icon associated in order to warn of a well-configured or a non-configured item, and by moving the mouse over an axis item, a tooltip displays the status. See Fig. 18.

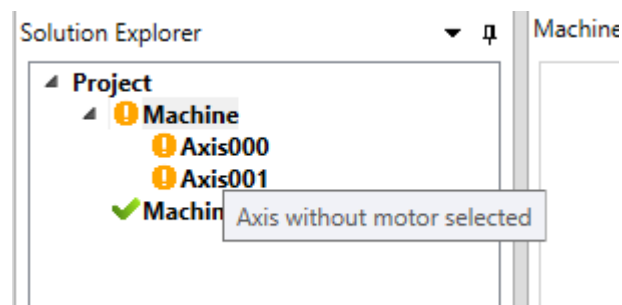


Fig. 18 Solution Explorer item status

The possible statuses for the axis are listed below:

- Axis is Ok
- Any linked axis is incorrect (when a group axes is defined).
- Axis without profile defined
- Axis without motor selected
- Axis without motor defined
- Axis without mechanical elements defined
- Axis without drive selected
- Axis without connection between motor and profile
- Axis with more than one profile defined
- Axis with more than one motor defined

- Axis is empty
- Axis elements connection mismatched
- Link required between integrated motor and power supply.

The machine is well-configured when all the inside elements, are also well-configured.

4.2.3. Property Grid

This window is used to view and edit the design-time properties of selected items that are located into the workspace of the tool. It includes edit boxes, drop-down lists and other controls to facilitate the configuration of the all items. Some properties may be read-only. When one property is edited, the tool updates the linked properties and the calculations.

Fig. 19 shows the property grid when a suspension element is selected. Input data, Output data and miscellaneous information are split.

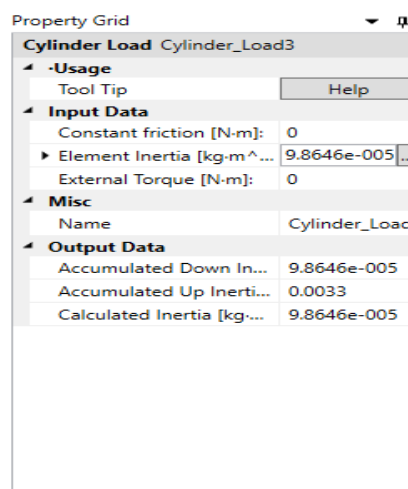


Fig. 19 Property grid

Some properties have an associated button, which open a window helper (e.g. inertia calculator). All items present a Help button in which a tooltip window is opened at top level helping the user to identify the key fields of the item.

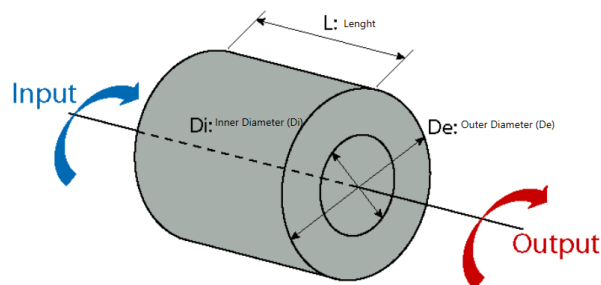


Fig. 20 ToolTip example for the particular case of a cylinder load.

The property grid will be an unique grid for Full projects related, as mentioned, to a suspend and selected item. In Lite projects each axis' item should have its own simplified version of the property grid in below of the corresponding suspension element.

In case of an axis with the mechanical element Pinion Rack with Moving Pinion, the proper Element Inertia permits to enter mass directly in some components. These components are the Pinion Rack with Moving Pinion (rack mass) itself and GearReducers, as detailed in Fig. 21

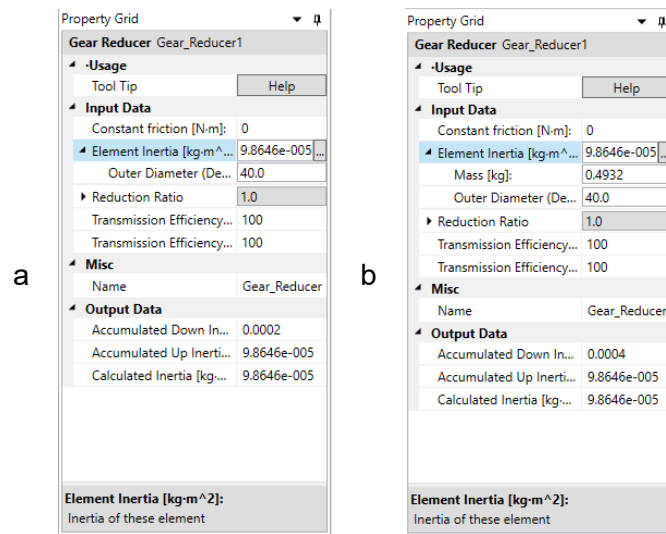


Fig. 21 Property grid Element Inertia detail. a. Axis without Pinion Rack with Moving Pinion. b. Axis with Pinion Rack with Moving Pinion

4.2.4. Workspace and toolboxes

The workspace consists in a background with the general view of the project. Multiple tabs can be opened, so the user selects the active one. By double clicking an item in the Solution Explorer, the corresponding tab is opened.

- Machine tab:

- Includes the machine picture background with axes on top. The picture can be modified from machine property grid.
- Axes and power supply can be dragged and dropped from the machine toolbox. This toolbox loads the axes included in "...User/MyDocuments/MotorSizingTool/AxesToolbox" folder.
- Items can be moved and resized.
- By double clicking an axis icon, the corresponding tab is opened.
- By left clicking an element, it will be selected and displayed in the property grid. 'Supr' keyboard deletes the selected item.
- Each machine is associated with one controller, so this element can be modified but not removed.

- Axis tab:

- The axis tabs have clear differences according to if a Lite or Full project is created.
- Both project types include the background where the kinematic chain with the mechanical elements, the motor and profile are built.

○ An auto-alignment button (see Fig. 22) allows to align mechanical elements as follows:

- If no elements, Auto-align command has no effect
- If no motor, all other items are aligned
- In case of multiple sub-chains in the canvas, each one is auto-align and located one below the other. If also exists alone mechanical items in the canvas they are also align at the most bottom line

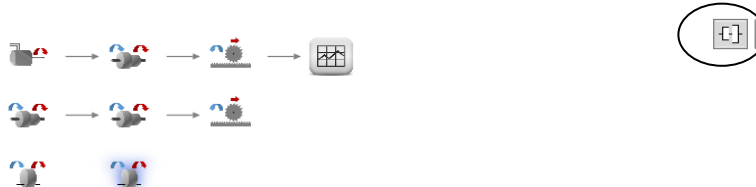


Fig. 22 Auto-align button

○ An auto-connect button allows to connect mechanical elements (see Fig. 23). The Target is to create one unique valid kinematic chain that starts with a motor, has several mechanical elements and ends with a profile. The connection criterion is as follows:

- If there is already a valid kinematic chain, no action will be done and if there are some non-connected elements, they will remain unconnected.
- If there are already some pre-connected elements, this link will be respected (in the example, gearbox and ballscrew will behave as an unique element that is rotary input and linear output).
- First element is the motor. If there are several motors the criteria is:
 - Priority is: Omron rotary □ Omron linear □ Third party rotary □ Third party linear if there are rotary and linear elements to be connected.
 - In case there are more than one motors of same type, the priority is by proximity to the top-left corner.
- Last element is the profile.
 - In case there are several profiles the priority is by proximity to the top-left corner.
 - Profiles other than the non-priority one will keep unconnected.
- Elements after a rotary motor follow next priority:
 - Gearbox (only the closer to top-left corner if several gearboxes)

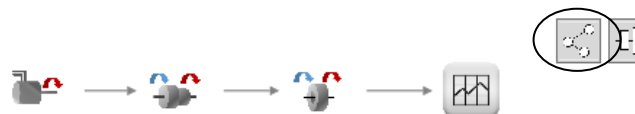


Fig. 23 Auto-connect button

Full axis tab

- Includes 'Application Results' and 'Devices Selection' windows in the bottom.
- The mechanical elements can be dragged and dropped from the axis toolbox.
- By right clicking an item, a commands menu is opened and the plots tab can be opened.
- By moving the mouse over an item, four visual elements will appear at each side of the item. By clicking them with the left mouse button and start dragging, an arrow is created to connect two elements.

- The elements can be connected, if the movement type between them is compatible. The direction of the connections must be from motor to load.
- By left clicking an element, it will be selected and displayed in the property grid. 'Supr' keyboard deletes the selected item.

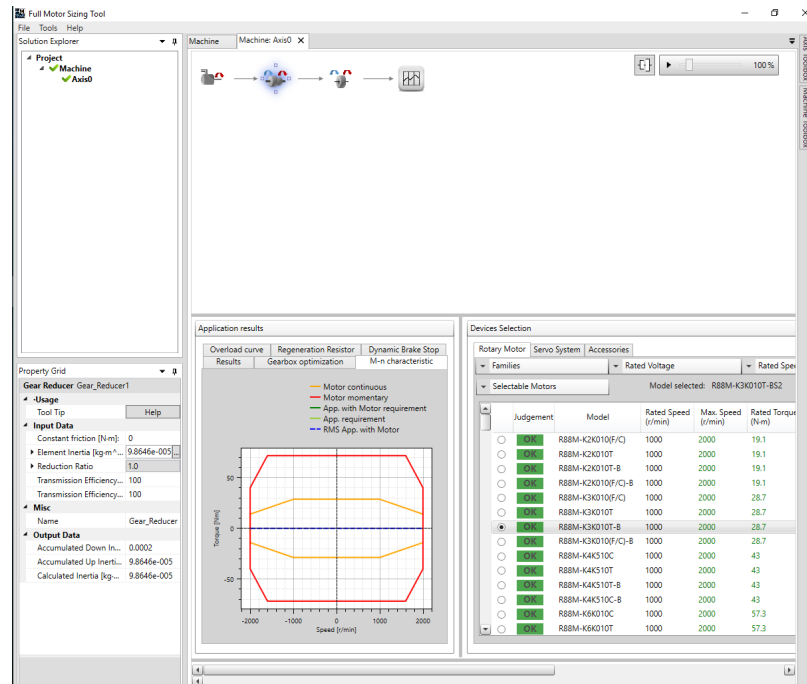


Fig. 24 Axis tab for full projects

Lite axis tab

- Only can be loaded predefined valid axis. Any pre-saved axis that contains a mechanical CAM, lever, linear balancer, crank, gantry and XY coupling will trigger a pop-up message indicating an incompatibility with Lite project type.
- 'Devices Selection' windows in the bottom that embeds Results summary.
- By moving the mouse over an item, four visual elements will appear at each side of the item. However, axis cannot be modified, even in terms of adding or remove current elements.
- Each element disposes of a simplified version of its equivalent version in Full in below. If the element is displaced to another position, the property grid will follow the item.
- If a profile is in the chain, the scope property permits to select to see position, speed (default) or acceleration. To change the profile instruction, double-click on the profile should be done. Number of instruction (maximum 2 instructions) and type of instruction are limited (triangular, trapezoidal and trapezoidal advanced).

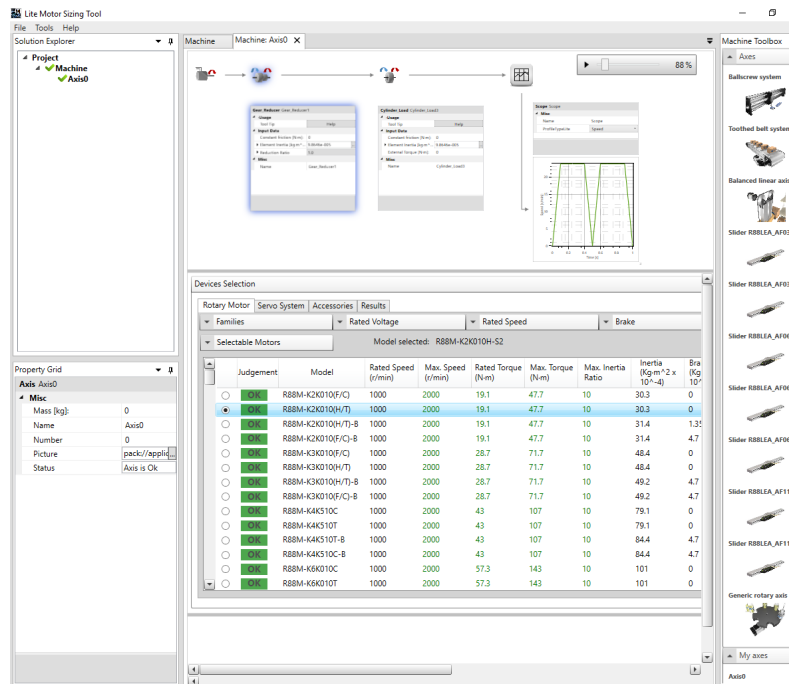


Fig. 25 Axis tab for Lite projects

- **Plots tab (only for Full projects):**

- Displays the motor side and load side graphs with the position, speed, torque/force and power of the selected element.
- Plot events (useful for all graphics of the tool):
 - Pan: Right mouse click
 - Zoom: Mouse wheel, '+', '-' keyboards
 - Zoom by rectangle: Ctrl + right mouse click, Wheel mouse click
 - Show 'tracker': Left mouse click
 - Reset axes: 'A' keyboard, Ctrl + double right mouse click, double wheel mouse click
 - Copy bitmap: Ctrl+C

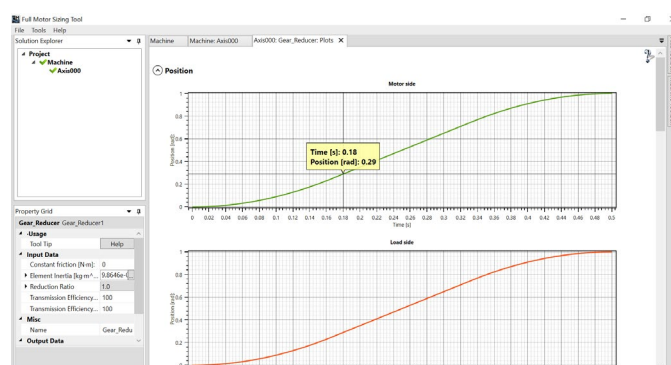


Fig. 26 Plots tab

5. Motor/drive sizing

By double clicking an axis, either in machine tab or in solution explorer, the corresponding axis tab is opened.

Each axis has an independent configuration tab window. This tab is mainly split in 3 parts:

- **Axis window:** it is possible to move, delete and insert mechanical elements from the axis toolbox in Full projects. The mechanical components are divided into groups according to their type of input/output movements:
 - Rotation to Rotation: inputs rotation and outputs rotation, which are the gear reducer, gear, belt transmission, cylinder load, eccentric, rotational block, variable inertia load and eccentric vertical load (affected by gravity).
 - Rotation to Linear: inputs rotation and outputs linear movement, which are the ballscrew, nut rotating, belt conveyor, roll feed, suspension, pinion & rack with moving rack and with moving pinion, winder/unwinder, mechanical CAM and crank.
 - Linear to Rotation: inputs linear movement and outputs rotation movement, which is the rack & pinion.
 - Linear to Linear: inputs linear movement and outputs linear movement, which are the linear mass, variable linear mass, balancer, axis carrier, lever and slider.
 - Special mechanisms which is the splitter.

The splitter element allows define the number of branches on the motor side, so the number of motors is multiplied. A branch is defined and the others are cloned. Thus, each motor only works under 1/branches of the load. The part-list of accessories is updated consequently.

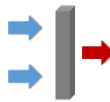


Fig. 27 Splitter element

The mechanical CAM cannot be positioned at the left of a motor. In case of using a mechanical CAM within the axis, the profile should be located at motor left and only a constant instruction can be used.



Fig. 28 Splitter element

The variable linear mass or the variable cylinder load can only be positioned at the left of a Profile Editor. Only one is allowed per axis.

The eccentric vertical item contains a check-box to introduce initial position that should be set on profile editor first instruction. The origin angle (0°) is pointing down in the vertical direction.

Each change realized in the element's properties, launches the calculations automatically and the kinematic chain is updated dynamically.

As shows Fig. 29, scopes can be added in any point of the kinematic chain.

- **Application results:** includes the results of calculations and some useful features. All available in Full project. For Lite projects, only Results tab is embedded into Device selection tab.

- Parameters of interest in the motor side of the axis (e.g., maximum torque and speed, inertia...). Some of them are split between with/without motor. The difference is whether the inertia of the motor is included or not, respectively. Also, the main ratios between application value and motor parameter are shown.
- M-n graph: motor torque-speed curve on top of application torque-speed curve.
- Overload level applied to the motor during repetitive cycles.
- Regenerative resistor analysis: useful to calculate the most suitable braking resistor. The drive has a limited capability of accumulate or dissipate the regenerated energy so, when the regeneration is big, the regenerated energy is burned as heat in a power resistor. DC bus voltage, power after drive losses and power in resistor are plotted.
- Dynamic brake is the functionality of the servo system that guarantees a relatively fast stop of the servomotor in case of a power failure. The analysis developed in the tool is useful to calculate the stop distance of the motor in the worst case of maximum speed with maximum load. Distance travelled and speed evolution are plotted.
- Overload level applied to the motor during repetitive cycles.
- Gearbox optimization permits to compute the optimal reduction ratio for those axes in which as GearReducer element is used. Can be only launched if the axis is valid and, at least, contains one gear reducer component. The outcomes are the inertia, torque and speed of the axis with and without considering a motor. It highlights in red and green the not allowed and optimal ratios, respectively. The user can select the initial and final ratio. As the optimization can require sensitive time, the user can start the optimization and cancel it when desired. A progression bar indicates the progression of the optimization. A tooltip button indicated by a question mark picture gives provides more details.



Fig. 29 Axis window for Full projects

- **Devices selection tabs:** allows motor, drive and accessories selection. All the information displayed is contained in the database.
 - Motor selection: displays a list of the selectable motors, which can be modified using the selection filters of family, voltage, speed and brake. Different list boxes permit to filter according to four criteria; motor family, rated voltage, rated speed, brake or judgment criteria result. Each motor has a judgement according to the criteria below:
 - OK (green): motor that matches the requirements.
 - Not Good (red): the motor torque-speed curves are smaller than the required by the application or $J_{load} > 2J_{max}$.
 - Warning (orange): the motor torque-speed curves are OK for the application but there is other criteria that does not match like excessive inertia ratio ($J_{load} < 2J_{max}$ and $J_{load} > J_{max}$) or overload level warning.
 - Drive selection: after the preselection motor model, the final motor model name is defined according to the encoder, oil seal, shaft and connector selected. After that, the corresponding list of selectable drives is shown.
 - Accessories selection: after motor and drive selection, the part-list of accessories is created. When the accessory is a cable, the length is selectable. The selected accessories will be added to the part-list.

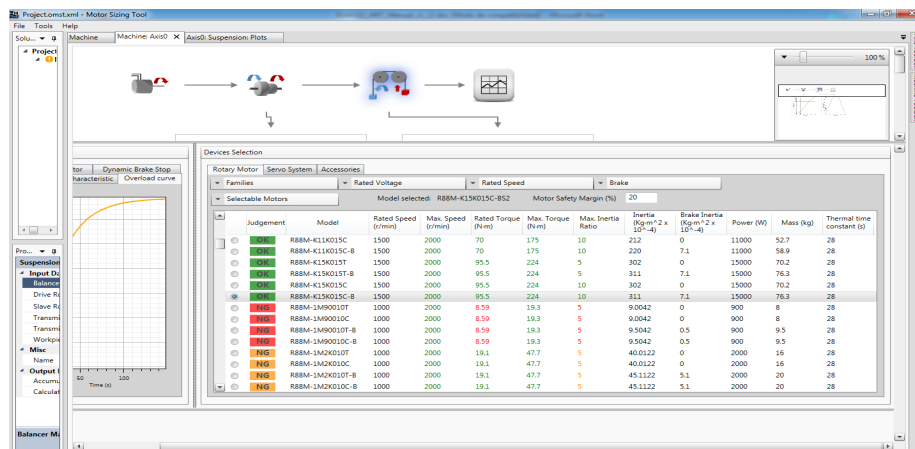


Fig. 30 Motor selection tab

For Lite project, predefined axes with linear motor with name: “Slider R88LEA_XXXXX” have a special behaviour.

- Motor and first linear mass are fixed and cannot be modified. Property grid of those elements is fully greyed. Motor cannot be changed.
- Second mass and profile is customer selectable.
- By default, only valid motors are shown in the motor list.

5.1. Operational Flow

Certain steps are recommended to follow in order to achieve the motor and drive sizing.

- 1- Insert the mechanical elements, the motor and the profile. At least these elements must be dragged and dropped from the axis toolbox into the axis tab background.

- 2- Connect the elements and assemble the application in the desired order of elements. To connect two elements, the movement type must be compatible. It's required a complete connection between motor and profile through the elements. Profile item can be connected either in the motor side or load side of the axis.
- 3- Define the motion profile. The motion of the axis is defined via the Profile Editor window. A motion is required to correctly launch the calculations through the axis elements.
- 4- Customize the mechanical elements. After that all elements, which comprise the mechanical system, are inserted, their properties (dimensions, mass, etc...) should be inputted by using the property grid. For each modification in the elements, the kinematic chain will be automatically updated.
- 5- Select a motor from the list. When all previous steps are completed, the motor requirements are calculated and the judgement for each motor is displayed.
- 6- Select a drive that can be used with the motor selected in the previous step.
- 7- Select the accessories from the list.
- 8- Report the information. After check the results, the information can be reported.

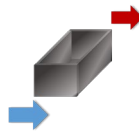


Fig. 31 Axis carrier element

Group axes are a special case of motor/drive sizing in the tool. In order to have an intuitive representation of group axes, there is defined one element called 'Axis carrier', which represents one axis in top of another. This is especially useful when all the elements of the mechanical chain cannot be represented in a plane (e.g., gantry system or XYZ system). When an axis is on top of the other axis, this will be represented in different tabs (e.g., Y axis on top of the gantry, then gantry axis will include the 'axis carrier', which indicates that gantry carries Y axis). Fig. 32 shows the hierarchical structure of a group axes in the Solution Explorer.

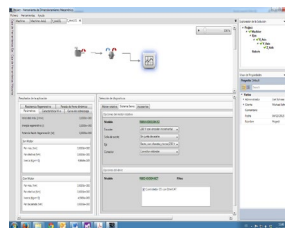


Fig. 32 Axes group in Solution Explorer

5.2. Profile Editor

By right clicking the profile item and selecting 'Open Editor Profile Window', or double-clicking the item, the profile editor is opened. See Fig. 33 for Full projects.

The motion profile describes how the mechanical application should move. This window allows define the motion by segments.

By clicking the 'Add instruction' button, a segment is added after the initial row, of which the initial speed can be edited. The selectable instructions are:

- Constant: keep initial speed for the selected time. Only duration is selectable.
- Ramp: starting from the initial position and speed, it will have always linear velocity, i.e. constant acceleration. Selectable items are time (always) and one of the next; (I) final position (then, speed and acceleration are calculated), (II) final speed (then, position and acceleration are calculated) or (III) acceleration (then, final position and speed are calculated).
 - A field S-curve time can be edited in order to add a trapezoidal acceleration behaviour. The S-curve time defines the acceleration (symmetrical for deceleration) time.
 - If S-curve time is 0 → Linear ramp with no S behaviour
 - If S-curve time is Instruction duration/2 → Only S, no linear part.
 - The S-ramp is symmetrical
- Import CAM: allows adding a profile from *.csv table (slave position vs time or slave position vs master position). According to the typical rules used in CSV files, when the decimal separator is a point then the default CSV separator will be a comma, but if the decimal separator is a comma, then the default CSV separator will be a semicolon. Both formats are accepted in the tool. Imported values can be averaged if the user enables the filter. The CAM file can be embedded into the project by selecting the corresponded checkbox so the .csv file is not needed anymore.
- Brake: keep initial position for the selected duration.
- Predefined triangular profile + dwell.
- Predefined trapezoidal 1/3 profile + dwell.
- Predefined advanced trapezoidal 1/3 profile + dwell. The motion profile permits to define can define separately:
 - Acceleration/Deceleration section in time or rate
 - Total duration and distance of the movement.
 - Depending on how data is entered the complementary section can be recomputed to obtain a consistent solution (note that in case of using rate control type could imply more than one solution. Then the tool proposes one as closes as possible to user inputs).

By selecting a segment, its properties can be configured. For each modification in the segment, the profile is automatically updated. Besides, each segment has some read only information:

- Duration.
- Final position/ speed / acceleration of the corresponding segment (read only).

At the bottom of the window, the position, speed and acceleration of the edited profile is shown.

By selecting the mechanical element, it's possible to show the effect of this profile in another element of the axis. The step time between points will be automatically calculated by the tool using an intelligent algorithm, in order to optimize the step increment compared to the duration of the profile.

When a variable linear mass or a variable cylinder is used, a new entry is requested per instruction (excluding first instruction). Default value is zero.

When a crank or eccentric vertical element is used and initial position is checked at its property grid a new entry is available to set the initial position. This value can be set at first instruction in the Profile editor. The default value is zero.

Finally, Ok and Cancel buttons, accept or discard the modifications.

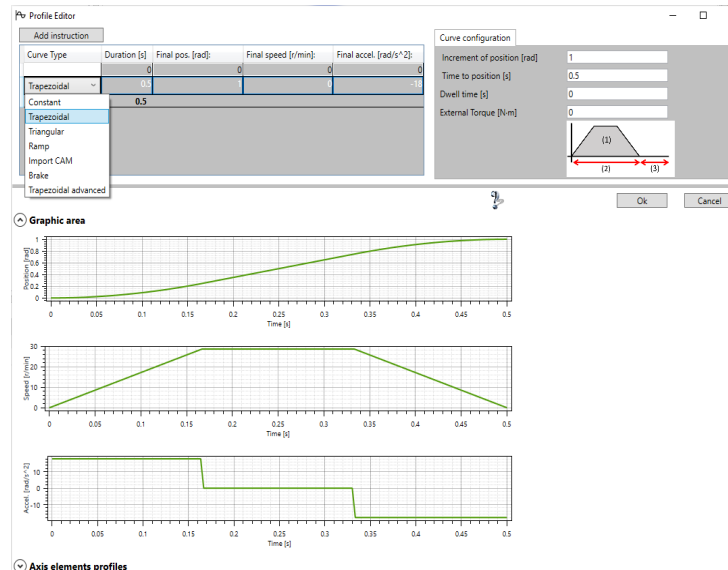


Fig. 33 Profile editor window for Full projects

In case of Lite projects, the Profile editor is limited to two instructions. It is not possible to add or delete instructions. Also, selectable instructions are limited to Ramp, Trapezoidal or Trapezoidal Advanced.

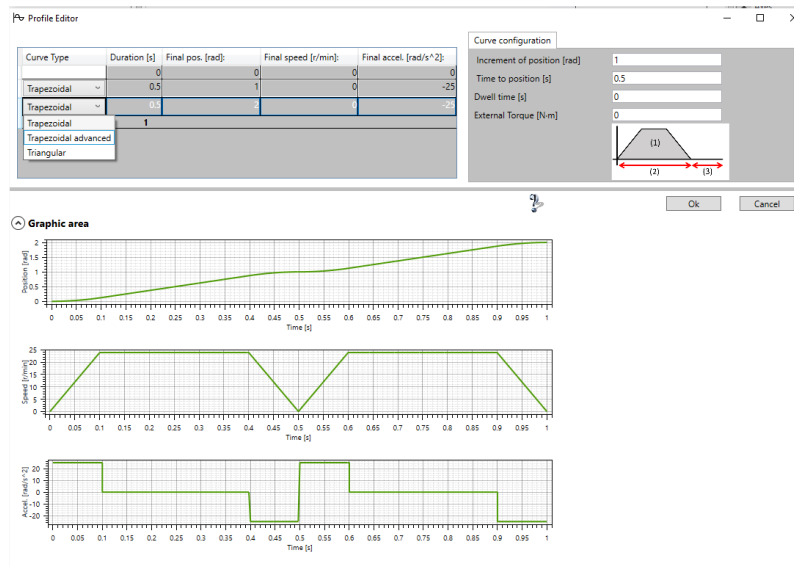


Fig. 34 Profile editor window for Lite projects

5.3. Inertia calculator

The inertia calculator provides a helper to calculate the inertia value for an element. This window is opened by clicking the button associated with the inertia properties in the property grid. See Fig. 35.

Cylinder and cuboid solid figures are selectable. By defining the dimensions and density of these elements, the corresponding inertia value is automatically calculated.

Predefined materials are selectable to define the density of the element. Otherwise, density can be inserted manually.

By checking the 'Direct Inertia Input' field, the inertia calculator is disabled and the value of the inertia can be defined manually in the corresponding edit box.

Inertia Calculator

Dimensions

Outer Diameter (De) [mm]: 40.0

Outer Perimeter [mm]: ☐ 125.664

Inner Diameter (Di) [mm]: 0.0

Inner Perimeter [mm]: ☐ 0.0

Length (L) [mm]: 50.0

Volume [mm]³: 6.2832e+004

Eccentricity (ecc) [mm]: 0.0

Materials

Material: Steel

Density [kg/m³]: 7850.0

Load mass [kg]: 0.4932

☒ Direct inertia input ☐ Direct mass input

Inertia [kg-m²]: 9.8646e-005

OK

Fig. 35 Inertia editor window for Full projects

In case of Lite projects, some fields are not available. The not available field depends on the axis items. This kind of behaviour affects ball screw, nut rotating, rack pinion, gear, belt conveyor, belt transmission, suspension and winder/unwinder.

Inertia Calculator

Dimensions

Outer Diameter (De) [mm]: 100.0

Outer Perimeter [mm]: ☐ 314.159

Inner Diameter (Di) [mm]: 0.0

Length (L) [mm]: 50.0

Volume [mm]³: 3.9270e+005

Materials

Material: Steel

Density [kg/m³]: 7850.0

Load mass [kg]: 3.0827

☐ Direct inertia input ☐ Direct mass input

Inertia [kg-m²]: 0.0039

OK

Fig. 36 Example of Inertia editor window for Lite projects corresponding to a belt conveyor

5.4. Linear motor coil temperature

It is estimated that all heat losses are due to motor Joule loss.

A linear iron core motor dissipates heat while it is in operation. The heat is transferred to the surrounding by conduction, convection and radiation. The motor is mounted to a machine and therefore conduction can be considered to be the major heat transfer. The rate the heat is transferred is measured and given by the Rth value of the motor.

The tool allows using a table on top of the motor. In this case, the new equivalent thermal resistance (table plus motor) is calculated. The dimensions and material of the table are data entry.

As a data output, the estimated motor temperature increase is calculated with/without the heatsink. A warning is shown during the motor judgement when the temperature increase is too high.

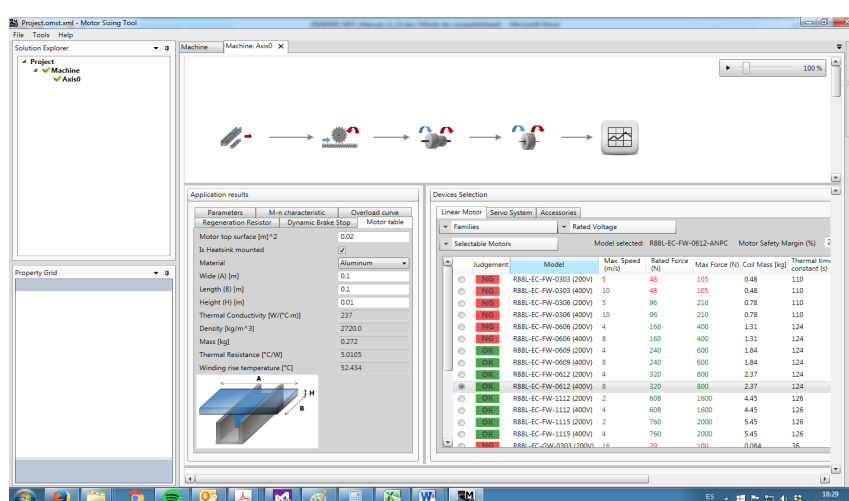


Fig. 37 Linear motor table tab

6. Power supply tab

When an Integrated motor is selected, a link between the motor and a power supply is required. The links are tied in the table shown on top of the machine tab, after a power supply is included. This option is only available for Full projects.

By double clicking a power supply in the machine tab, the corresponding power supply tab is opened. The current consumption of the power supply depends in the duty cycles of all the axes fed by this. Once the current consumption of the associated axis has been done, an alignment of the speed vs time graphs can be done, see Fig. 38.

- User is able to make a time shift for every motor graph.
- The profile for every motor is considered cyclic.
- User is able to modify the time period to show, as every motor profile has a different duration.

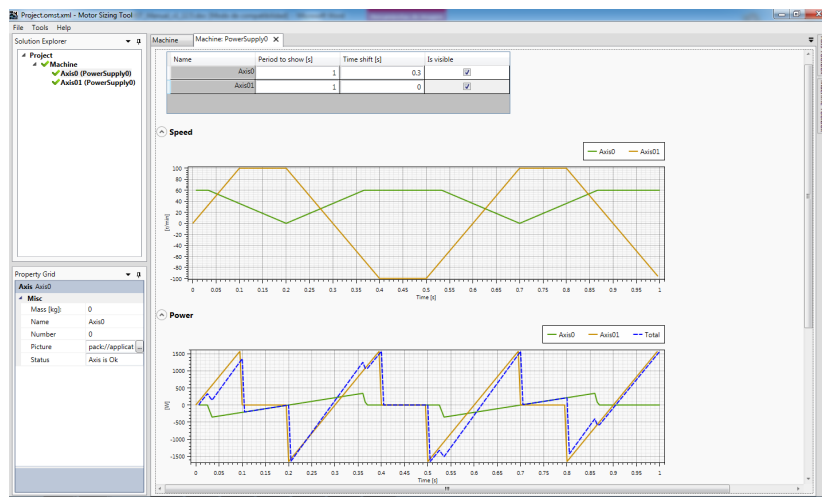


Fig. 38 Power supply tab (I)

As output the tool gives the required AC current vs time, the peak AC current and the RMS AC current. The supply voltage (400Vac default) is an input parameter. Finally, a judgement is applied to the available power supplies, as shown in Fig. 39.

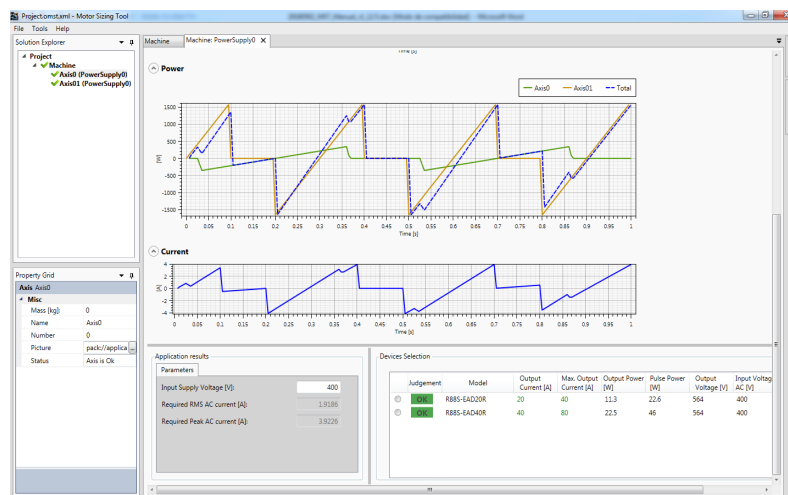


Fig. 39 Power supply tab (II)

7. Third party motors

The tool supports third party motors in Full projects. A couple of new icons (for rotary and linear third party) have been included to the axis toolbox in order to allow the use of these elements in the kinematic chain.

Once the project is saved, the third-party motor is embedded in the output file. Thus, in another computer, the third-party motors involved in the project can be exported and mixed with local third party libraries. If the project is opened in a new computer, the following behaviour can be observed:

- Create in Computer A a project with third party motor and opening the project in Computer B that does not have this motor. Result: New third-party motor is added in database in Computer B without dialogue.
- Create in Computer A a project with third party motor and opening the project in Computer B that already has this motor. Result: the project is opened in Computer B without dialogue.
- Create in Computer A a project with third party motor and opening the project in Computer B that has a motor with same name but different data. Result: the project is opened in Computer B with a dialogue that explains the conflict and offer to: (i) Update existing database, (ii) Add as new motor or (iii) Cancel opening. The differences are described in the dialogue.

When a third party motor is added to an axis, the selectable motors will not come from database but from a library. This library consist in a *.xml file stored in a "...User/MyDocuments/MotorSizingTool\ThirdParty" folder that defines the motor characteristics.

By selecting "Tools>Third party database" in the main toolbar, the third party database window is opened. This window allows adding and modifying the third party motors used in the tool. This wizard considers linear and rotary motors.

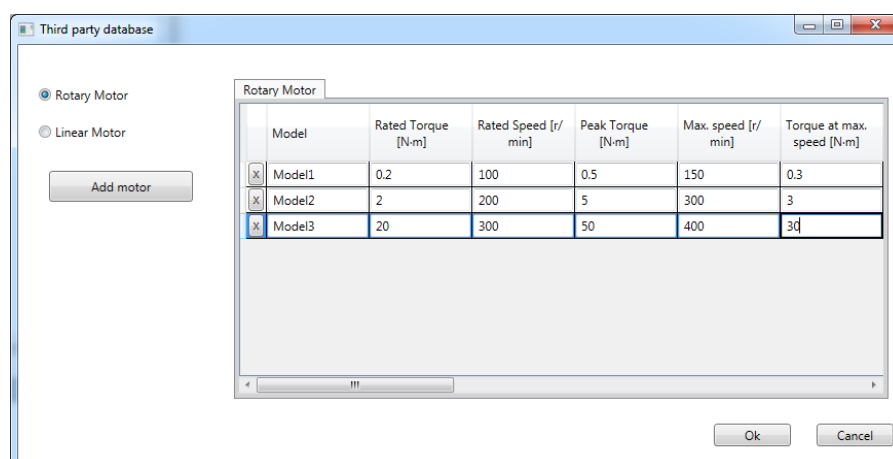


Fig. 40 Third party database modification

The data entry for third party motors is listed below:

In case of linear motor:

- Pole pitch (length of a N-S magnet pair) (mm)
- Motor Stall Force (N)
- Motor Stall current (Arms)

- Motor Rated Force(N)
- Motor rated speed (m/s)
- Force at maximum speed (N)
- Maximum speed (m/s)
- Motor peak Force (N)
- Coil mass (kg)
- Per-phase inductance (mH)
- Per-phase resistance (Ω)
- Thermal time constant (s)
- Power (W)
- Motor mass (kg)
- Max DC bus voltage acceptable
- Description

In case of rotary motor:

- Number of pole pairs (--)
- Motor Stall Torque (Nm)
- Motor Stall current (Arms)
- Motor Rated Torque (Nm)
- Motor Rated Speed (rpm)
- Torque at maximum speed (Nm)
- Maximum speed (rpm)
- Motor peak Torque (Nm)
- Rotor inertia ($\text{Kg} \cdot \text{m}^2 \cdot 10^{-4}$)
- Max. Inertia Ratio
- Per-phase inductance (mH)
- Per-phase resistance(Ω)
- Thermal time constant (s)
- Power (W)
- Motor mass (kg)
- Max DC bus voltage acceptable
- Description

Fig. 41 shows the M-n curve, to correctly interpret the motor data entry.

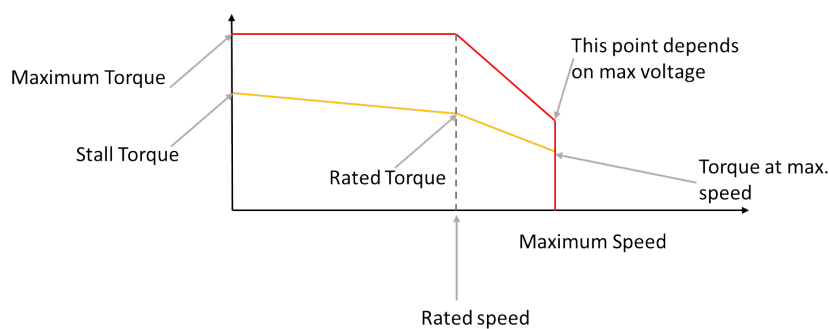


Fig. 41 M-n curve of third party motors

When this window is closed, the external *.xml file is updated according to the modifications applied.

Then, inside the axis tab, once a third party motor is included to the axis (by drag & drop the corresponding icon from the toolbox), the list of selectable motors appears. This is the list of motors

included in the *.xml file, as defined above. A judgement is applied to the motors list in order to guide the user when selecting one of them.

After a third party motor is selected by the user, the drive selection criteria are applied. The selectable drives are the G5 linear servo drive EtherCAT family. These drives can support linear and rotary motors. The criteria are:

- Drive rated output current \geq Motor stall current
- Drive Peak Output current \geq Application peak current
- Max frequency needed for max application speed $< 500\text{Hz}$ (if this is not true, no drive is valid).
- Max voltage needed $< \text{Drive supply} - 10\%$

After the calculations are applied by the tool, the user can select a drive which satisfies the requirements, if any.

Finally, no accessories are selectable for third party motors.

8. Data output

At the end of the process, there are a couple of possibilities of data output:

- Print a document report, which is also exportable to *.doc, *.pdf and *.xls.
- Export a *.xml file to Sysmac Studio program.

Only the well-configured items can be exported. If the user is trying to export a non-configured item, a warning message appears.

8.1. Document report

By clicking the command File > Print in the tool bar, the report viewer is opened, see Fig. 42.

At the top of this window, appears a list of the selectable objects to print.

By clicking the button 'Preview', the document viewer is updated with the selected items.

The document viewer provides a report toolbar to navigate through the document, export and print the document.

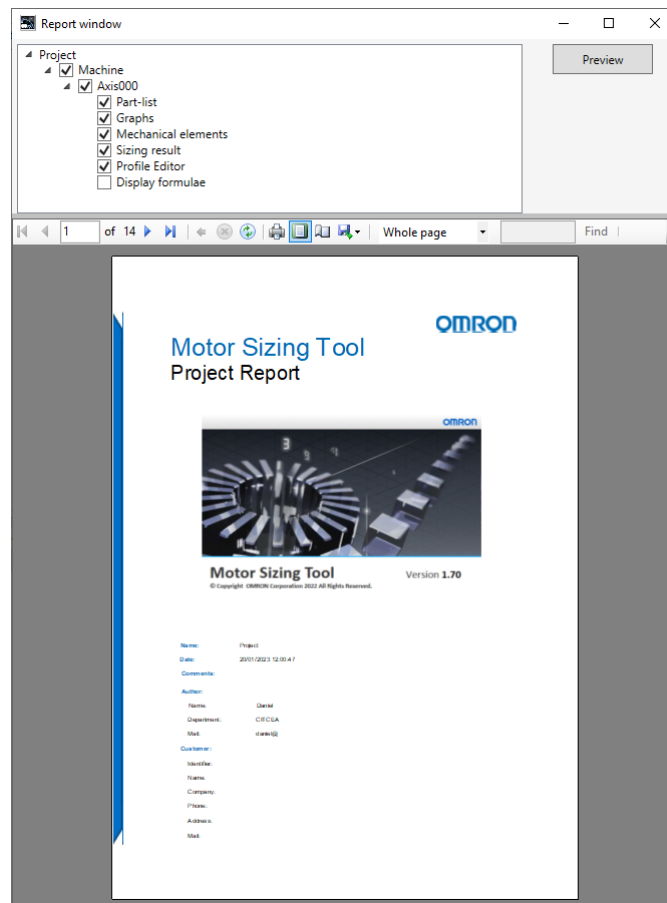


Fig. 42 Document report window

As abstract, in the exportable report will appear the information listed below:

- Project data:
 - General info: name, date, phone, comments...

- Customer info: name, company, address, mail, phone...
- Author info: name, department, mail...
- Machine data
 - General info: name, machine picture with the items icons on top.
 - Controller information: model, version, power supply...
 - Machine part-list of devices and accessories.
 - Axes Data
 - General info: name, number...
 - Application Torque-speed curve on top of motor Torque-speed curve.
 - Motor motion profiles; torque, speed, power vs time.
 - Axis part-list of devices and accessories.
 - Display formulae.

8.2. Export file to Sysmac Studio

By clicking 'File > Export' in the tool bar, a *.xml file is generated. As a data output, the project developed using the Sizing Tool can be reused to create a Sysmac Studio template project. To allow this, the output of the Sizing Tool should be able to export a *.xml file with the suitable structure:

- Project Property: name, date, author, comment...
- System Configuration: controller and axes devices information.
- NexAxis Settings: defines settings and parameters about the axes used in the sizing tool.
- NexAxis Group Settings: defines settings and parameters about the group axes used in the sizing tool.

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