BRUTOMIZER© Ver 1.1

Manual

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Example case study

Consider that using laser cutting experimental data two mathematical models for the prediction of surface roughness (R_z) and material removal rate (MRR), in terms of laser power (P), assist gas pressure (p) and cutting speed (v) were obtained as:

$$R_z = 240.3 - 18.9 \cdot P - 4.8 \cdot p - 111.2 \cdot v + 8.3 \cdot P^2 - 0.04 \cdot p^2 + 29.5 \cdot v^2 + 2.8 \cdot P \cdot p - 19.5 \cdot P \cdot v - 0.6 \cdot p \cdot v$$

$$MRR = 3558 + 11167 \cdot P + 1198 \cdot p - 16297 \cdot v - 1726 \cdot P^2 - 11 \cdot p^2 + 3124 \cdot v^2 + 106 \cdot P \cdot p + 116 \cdot P \cdot v - 387 \cdot p \cdot v$$

Suppose the developed mathematical models are valid in experimental hyper-space defined with the following ranges of variables: P = 3 – 4 kW, p = 6 – 10 bar and v = 3 – 3.5 m/min.

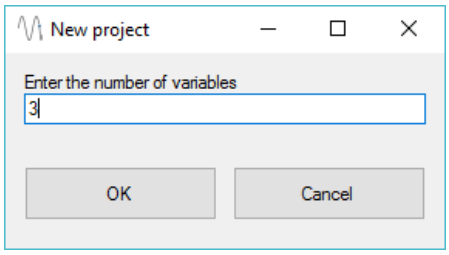
Capabilities of BRUTOMIZER© for solving various formulations of optimization problems will be illustrated on the afore-given case study.

NOTE:

Given example case study can be imported directly by clicking on the button *Import DEMO* (located on the top right) and selecting *Manual Demo* in the opened dialog. But before importing this demo, we strongly recommend that you follow the steps and examples given in this tutorial, as they will give you all the necessary information for using BRUTOMIZER©.

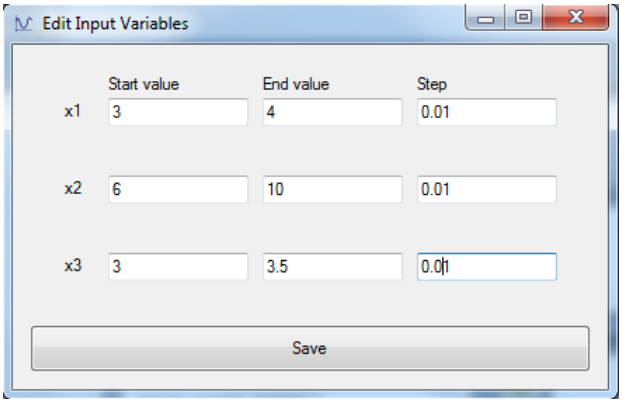
Step 1: Create New project

To create new project, one needs to click on the button *New* and enter the number of variables (for our case study, enter 3).



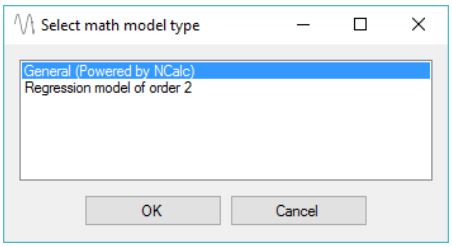
Step 2: Definition of variables ranges and steps

By clicking on the button  (located on the bottom left side of the main screen) one can define variable's ranges as well as step size of each variable. Considering the covered experimental hyper-space in our example case study, start and end values of each variable were selected and for, each variable, step size of 0.01 was selected. This means that © will consider 2065551 different combinations of variable's values.

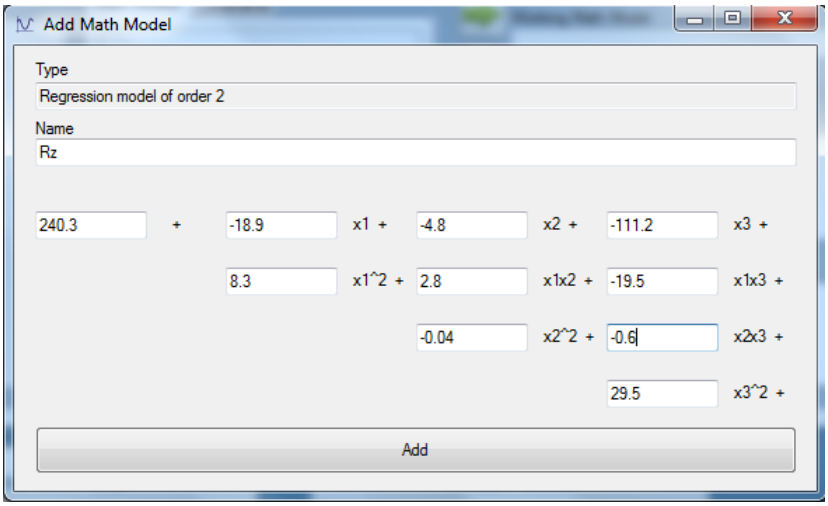


Step 3: Definition of mathematical models

Definition of given mathematical models is a necessary step. One needs to click on the button  in the *Math Models* tab (located in the center of the main screen) and select mathematical model type. Two types of mathematical models are offered by default: *General (powered by NCalc)* and *Regression model of order 2.*

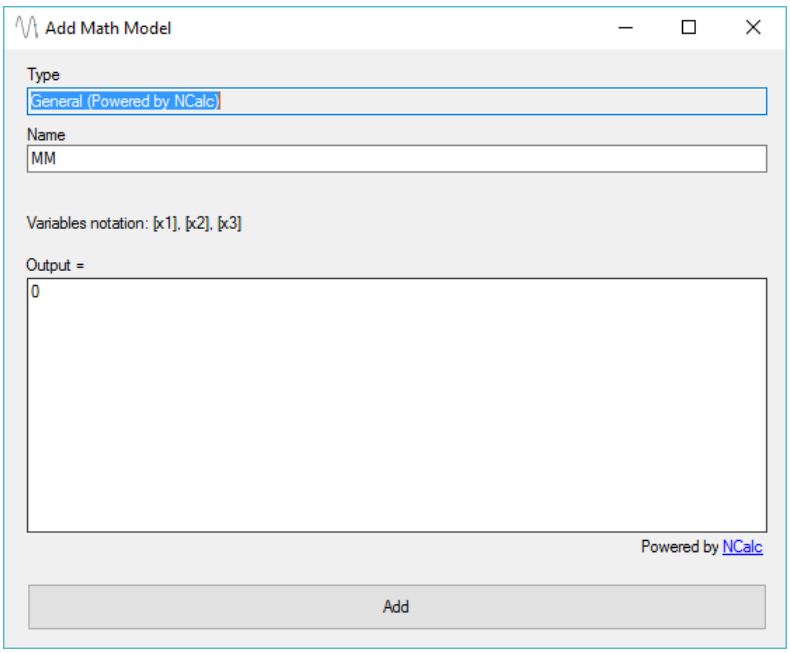


If desired mathematical model is a polynomial up to order 2 (with 2-way interactions), then one should select *Regression model of order 2* type. In the opened window, mathematical model for surface roughness (R_z) is defined by typing in the regression coefficients in the appropriate fields and finally by clicking the *Add* button. Note that x1, x2 and x3 stands for *P*, *p* and *v*, respectively.



The mathematical model for the material removal rate (MRR) is defined in the same manner as previously shown mathematical model for surface roughness (R_z).

If the desired mathematical model is more complex, then one should select *General (powered by NCalc)* type. This type covers a broad spectrum of mathematical functions and operators, and is powered by an open source library **NCalc** (https://ncalc.codeplex.com/). However, its generality affects its performance - working with this type of model can be much slower than working with *Regression model of order 2* type of model.



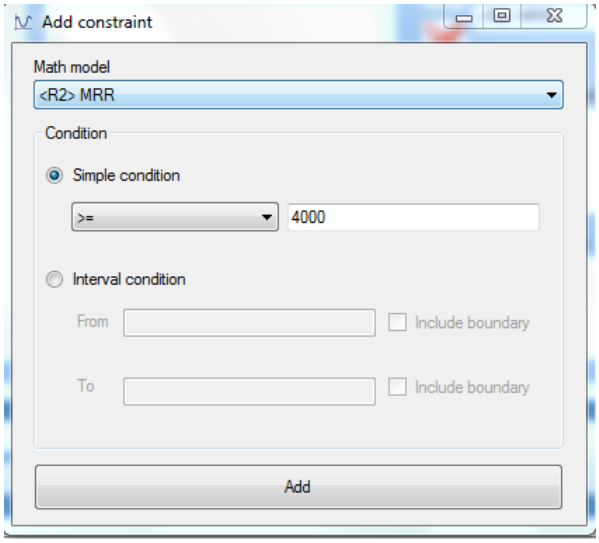
At any moment, given mathematical model can be edited by clicking on the button  , or deleted by clicking on the button  .

CUSTOM MATHEMATICAL MODELS

If you are dealing with billions of input combinations and complex mathematical models, it is smart to have your mathematical models custom developed – it can improve performance up to 100 times. Custom mathematical models can become available for selection in BRUTOMIZER©, just for You! Just contact us on http://www.virtuode.com/index.php/contact/.

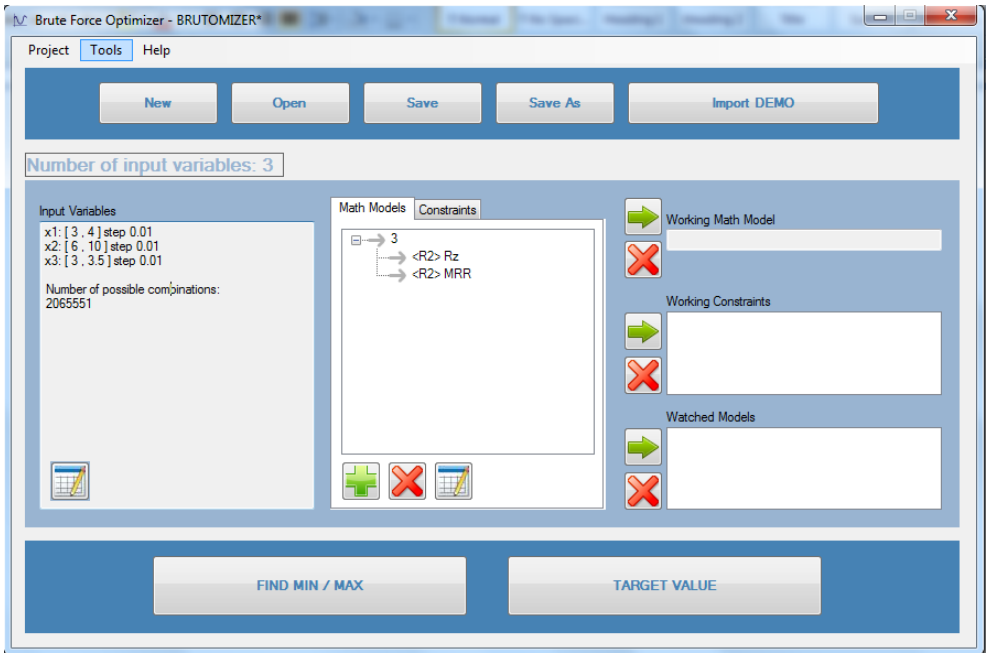
Step 4: Definition of constraints

Some formulations of optimization problems incorporate optimization constraints. In order to add constraint in BRUTOMIZER© one needs to click on the button  in the *Constraints* tab (located in the center of the main screen), select appropriate mathematical model and select condition (simple or interval). In our case, let's consider that MRR should be greater or equal to 4000 mm^3/min.



At any moment, given constraint can be edited by clicking on the button  , or deleted by clicking on the button  .

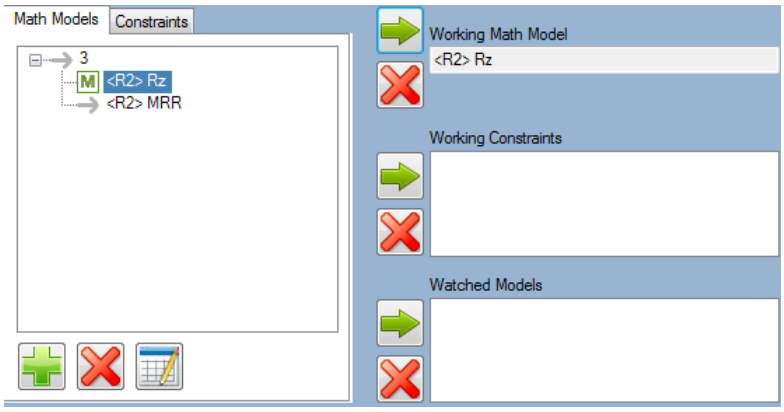
The main screen after definition of mathematical models, variables ranges and steps is as follows.



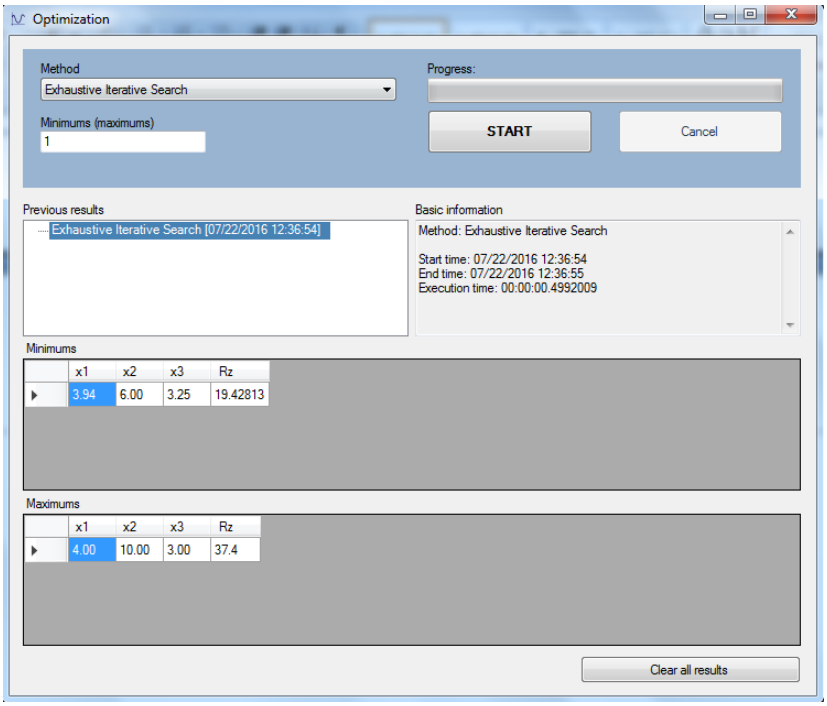
At this point it is a good idea to save current settings and defined input variables, models, constraints etc. This is performed by clicking on *Save* or *Save As* buttons on the top of main screen.

Example 1. Optimization without constraints

Let us consider that it is necessary to determine laser cutting parameters values so as to obtain minimal and maximal surface roughness. To this aim, one needs to select the defined surface roughness model in the *Math Models* menu and select  button so as to select this model as working model.



Afterwards one needs to click on  button in the lower part of the main screen to run optimization. Optimization is started by clicking on the button *START*. As it could be observed, BRUTOMIZER© determines extreme values (minimal and maximal) of objective function with corresponding values of independent variables for less than 1 sec. Note that BRUTOMIZER© can determine a larger number of optimization solutions (just type in the desired number in the *Minimums (maximums)* field).



Based on the obtained optimization solutions values, one can conclude that surface roughness varies between 19.43 and 37.4 μm.

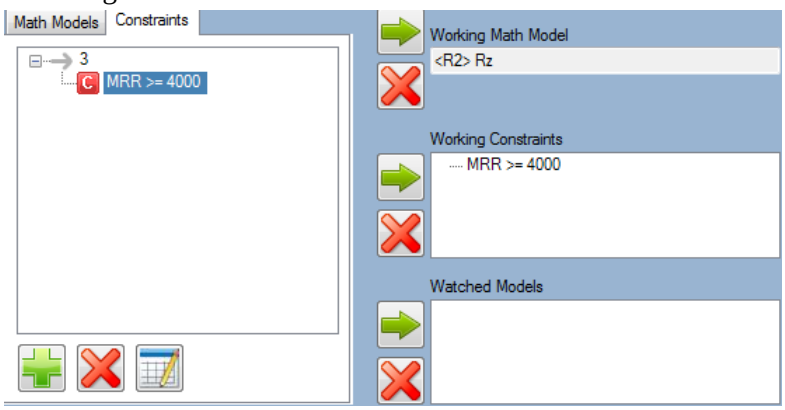
Similarly, it can been observed that material removal rate (MRR) varies between 3528 mm^3/min and 5238 mm^3/min.

Example 2. Optimization with constraints

Let us consider that it is necessary to determine laser cutting parameters values so as to obtain minimal surface roughness while maintaining MRR of at least 4000 mm^3/min. To this aim, one needs to do the following:

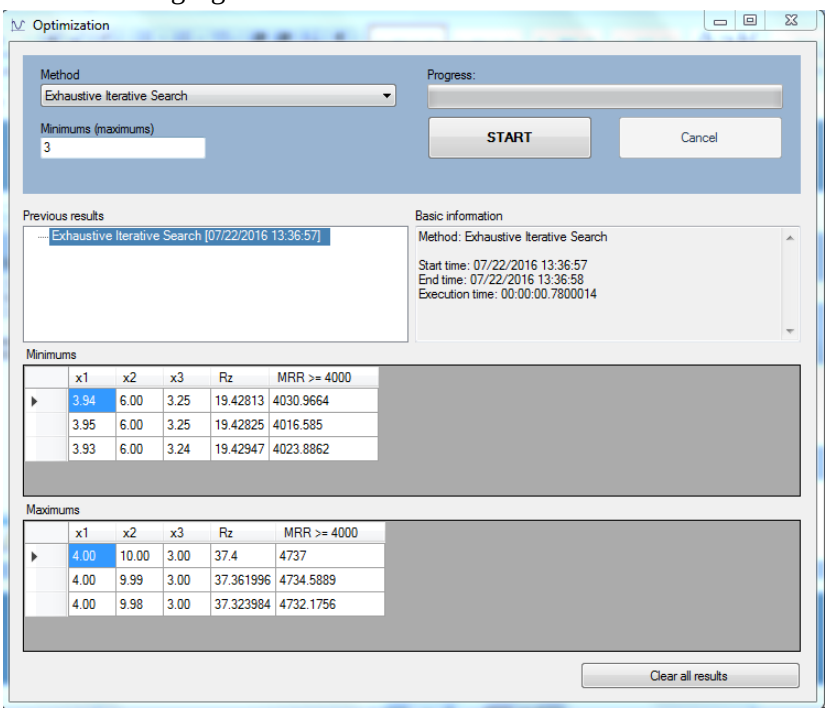
1) select the defined surface roughness model in the *Math Models* tab and click on  button so as to select this model as working model.

2) select the defined MRR constraint in the *Constraints* tab and select  button so as to add this constraint to the list of working constraints.



Afterwards one needs to click on 

button in the lower part of the main screen to run optimization. Optimization is started by clicking on the button *START*. Several determined optimization solutions are given in the following figure.



Example 3. Achieving desired objective function value

Consider that it is necessary to determine laser cutting parameter's values so as to obtain surface roughness of R_a=25 μm.

When the defined surface roughness model is set as working model one needs to click on 

button in the lower part of the main screen.

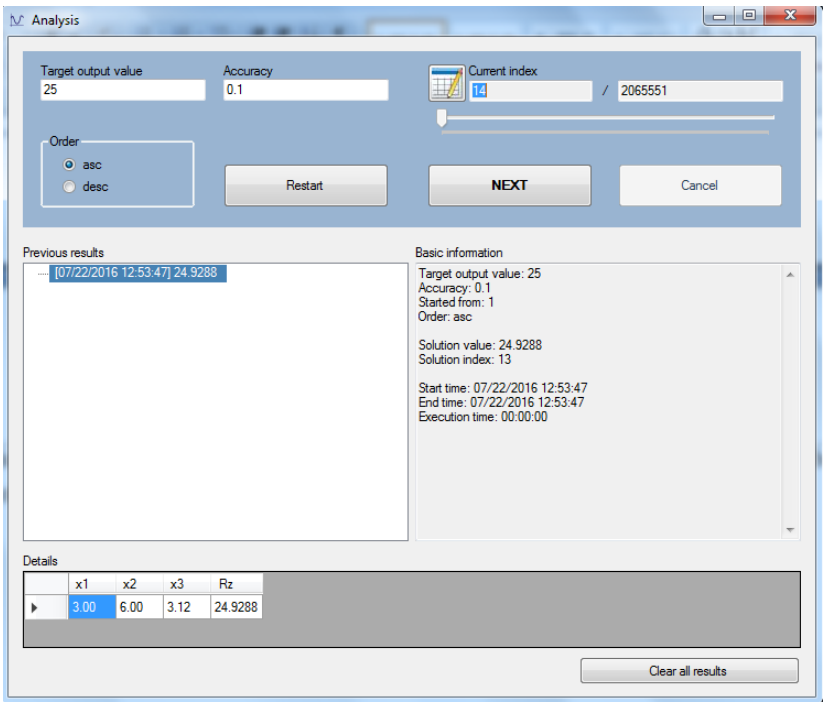
Based on the given target values for surface roughness and the desired accuracy Δ (maximum difference between the desired and calculated values of surface roughness) BRUTOMIZER© can determine the appropriate values of laser cutting parameters. BRUTOMIZER© can determine these values in two ways:

(1) starting from the smallest values of inputs i.e. laser cutting parameter values (*asc* option), and

(2) starting from the highest values of inputs (*desc* option)

Which option will be selected in the software prototype depends on the nature of the problem being solved and some other techno-technological aspects.

With selected *asc* option and accuracy of Δ=0.1 BRUTOMIZER© determines the solution given in the next figure. As it could be observed, surface roughness of R_z = 24.93 μm can be obtained by using laser power of P = 3 kW, assist gas pressure of p = 6 bar and cutting speed of v = 3.12 m/min.



Example 4. Achieving desired objective function value with constraints

Procedure of selecting constraints is given in Example 2. From then on, one needs to follow the procedure given in Example 3.