Consultants in Quantitative Methods

User Manual
CQM Tolerance Designer

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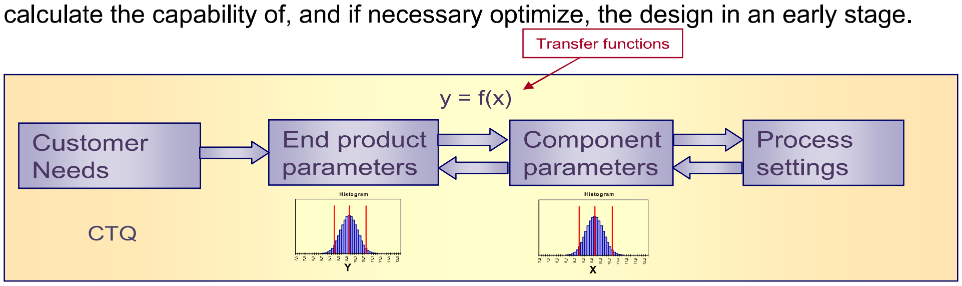
Reference PP/09153/Shw/ps

Contents

1. About CQM Tolerance Designer

The CQM Tolerance Designer is a software tool that has been co-developed by Philips Consumer Lifestyle and CQM (Consultants in Quantitative Methods) located in Eindhoven. We kindly acknowledge Sjoerd Haites who wrote the first version of this manual.

The CQM Tolerance Designer is intended to enable a uniform approach in tolerance analyses, linked to Design for Six Sigma (DfSS). It supports the engineer to calculate the capability of, and if necessary optimize, the design in an early stage.



In general every design's end product parameter can be described by means of a transfer function. Such transfer functions describe the mathematical relation between end product parameters (e.g., play between parts or switch force) and relevant input parameters (e.g. part dimensions or spring stiffness).

By means of a compact user interface the CQM Tolerance Designer provides useful functionality to help the engineer in evaluating and optimizing the capability of the design. This functionality includes:

- Input of relevant statistical distributions to represent realistic tolerances for the input parameters including the so-called "process tolerance" type to describe "off-target" processes
- Input of arbitrary transfer functions including non-linear ones
- Prediction of end product parameter capabilities (cp/cpk, etc.)
- Slider bars for settings of input parameters enable real time re-calculation of capabilities which are useful for optimization purposes
- Insightful representation of %spread contribution of input parameters (impact tables)

2. Installation and settings

The first time you install the software on your computer a special (copy protected) memory stick is necessary. This first installation will usually be done by your local tool owner or IT system manager, and requires the following steps:

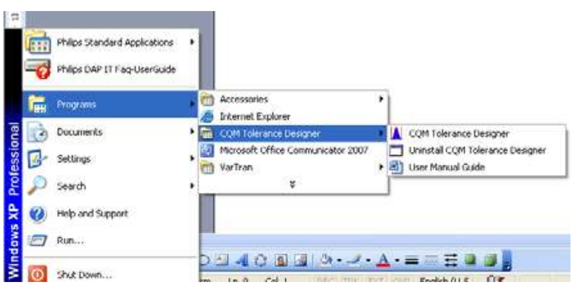
1. Execute vcredist_x86.exe
2. Execute ToleranceDesignerVxxSetup.exe with default settings.

A shortcut will be made on your desktop automatically and the application will be started.

Note: The first step may not be necessary; you could also try installing without vcredist_x86.exe. If installation and running the Tolerance Designer fails, you should then follow steps 1 and 2 again. Vcredist_x86.exe is downloadable from the Microsoft website.

Once the Tolerance Designer software has been installed on your computer, updates of the software can be easily installed only by running the ToleranceDesignerVxxSetup (step 2 described in this chapter). Now the mentioned special memory stick is not necessary, so in practice you may receive updates via e-mail or the internal web via your local tool owner or IT systems manager. This is also your contact person in case of problems with the software.

The program can be started via the Windows start pop-up menu under “Programs”. Also the User Manual is available here.



3. General lay-out and user-interface

The Tolerance Designer contains 4 functional tabs:

1. **Input** tab which enables you to set up the relevant input and output parameters of the tolerance calculation of your design.
2. **Histograms** tab which shows the capability plots of all selected parameters, incl. sliders to help you optimize the input parameter settings of your design.
3. **Impact Stdev** tab which represents an overview of contributors to the variation of each Output parameter. In fact, it can help you to optimize the Cp value of an Output parameter.
4. **Impact Mean** tab which represents an overview of contributors to the mean value of the Output parameter. In fact, it can help you to optimize the Cpk value of an Output parameter.

In general all buttons available in the Tolerance Designer are explained by a tooltip, and are colored when active or grey when inactive like Windows. Once starting the Tolerance Designer, the Input tab is inactive, because no case file is loaded.

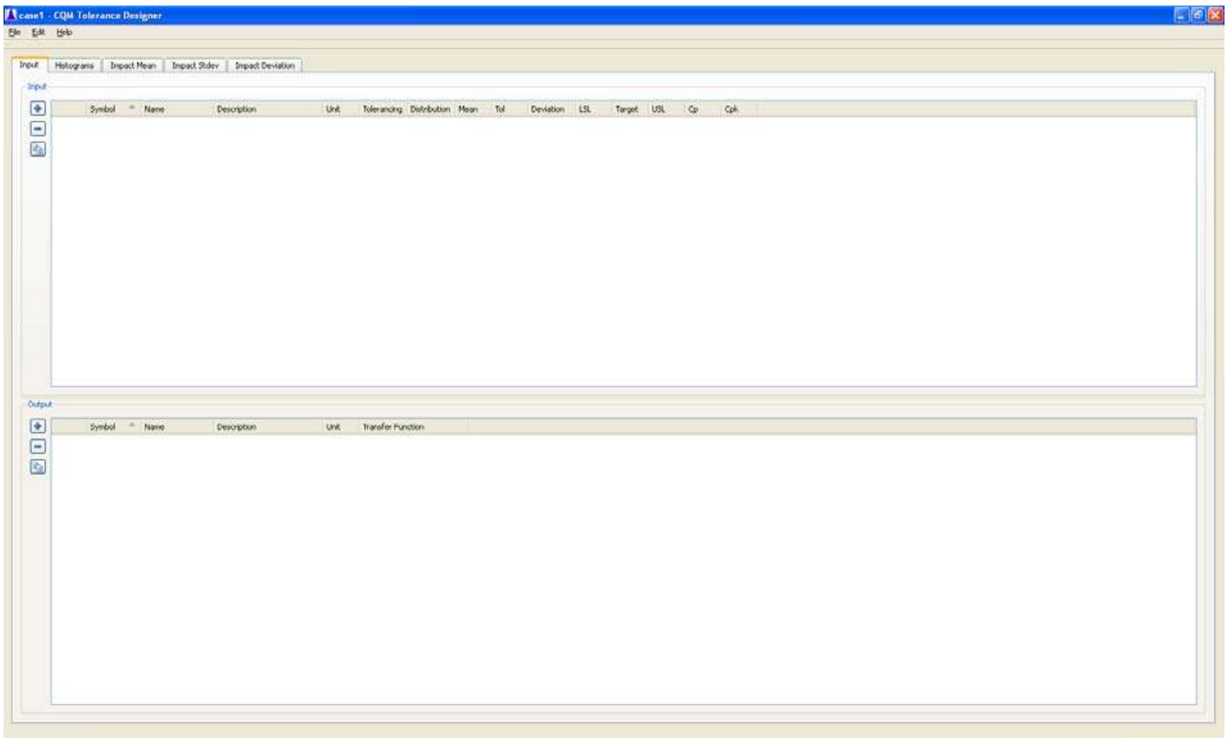
By clicking <File> the files dialog screen pops up, via which a case can be created, opened, closed and saved.

When the input tab is active, it is possible via <Edit> to enter a settings window and change some default settings of the software. ; see Chapter 7.

Via <Help> this User Manual is available.

4. Entering input and output parameters

This chapter describes how to enter input-output parameters information in the Tolerance Designer and how to display and store information.



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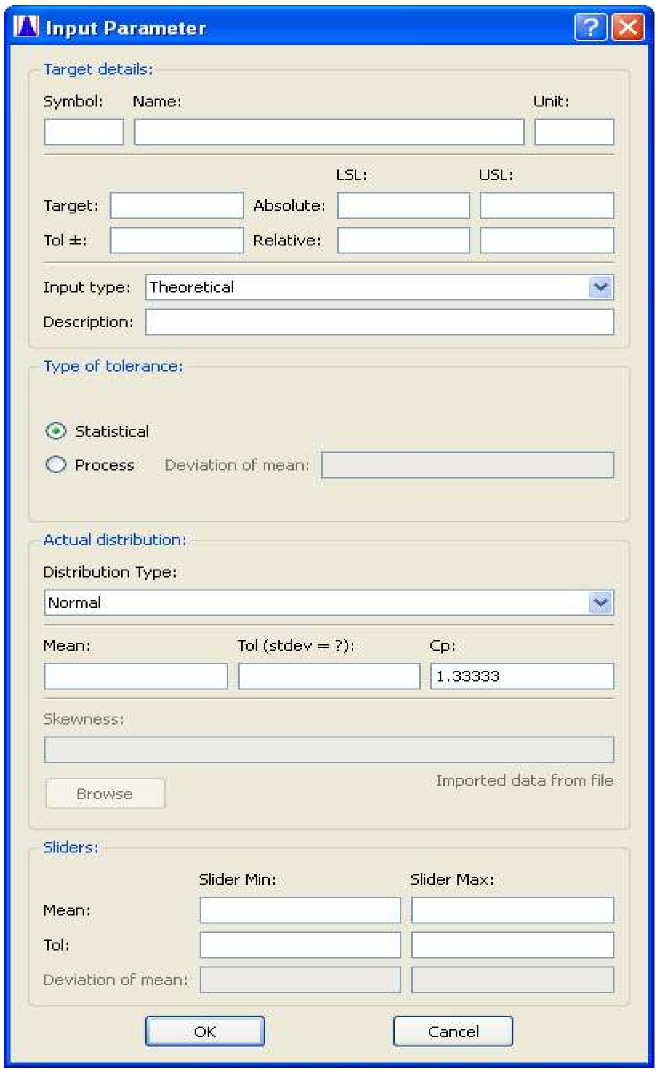
A brief explanation of some buttons of the Input tab is stated below.

add new input or output function

delete input or output function (this can also be done by selecting the function in the input tab and press <delete> knob on your keyboard)

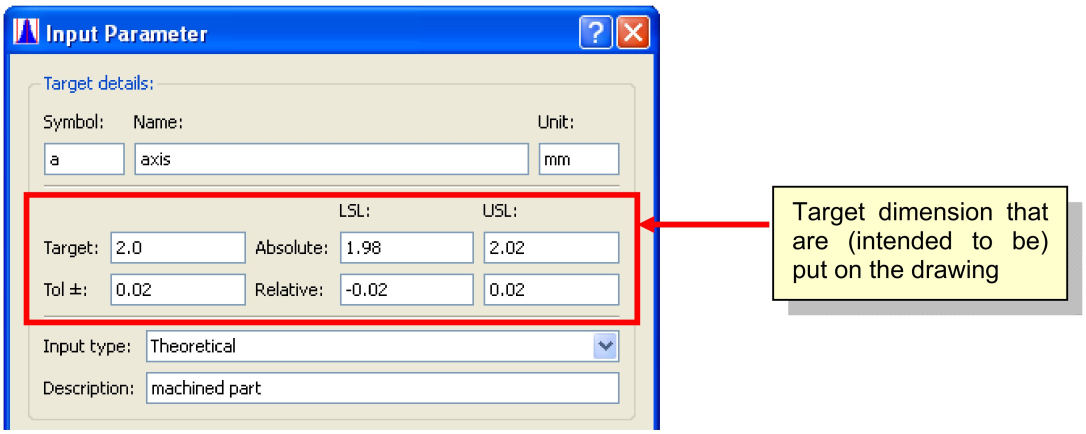
copy input or output summary table to your clipboard (e.g., for reporting purpose in Word or Powerpoint)

When entering an input parameter, the following **Input Parameter** dialog pops up.



The **Input Parameter** dialog is divided in 4 information group boxes.

1. **Target details**: contains general information of the input parameter including the targeted values for the input parameter.



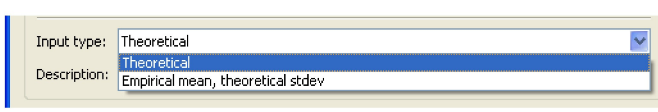
Basically, only the input cells **Symbol:, Target:, Tol ±:** are mandatory to fill in. The input cells **Name, Unit, Description** are not mandatory to fill in, but are recommended to use for clarification of the input parameters. For a new defined input parameter, the other cells will be filled initially with a default value by the program, once you have filled in **Symbol:, Target:, Tol ±:** cells. This default values are related to the entered values of **Target:, Tol ±:**. However it is possible to change the values by hand as will be explained later on. You can switch through all inputs cells by using the <Tab>.

Most input cells of this block are self-explaining, however with respect to some of them any specific explanation:

Target: nominal (= targeted) value of the input parameter
Tol±: symmetrical tolerance field around target
LSL: Lower Specification Limit = Lower tolerance limit (= target – tolerance)
USL: Upper Specification Limit = Upper tolerance limit (= target + tolerance)

In most cases the tolerance field will be filled in by just typing the tol± value. However, it is also possible to define a tolerance field by typing the relative or absolute LSL, USL values. In case of an asymmetric tolerance field, the **tol±**: field will become “inactive” (cell is empty and grey).

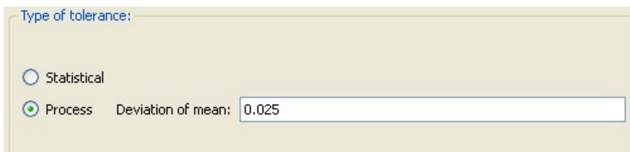
Input type: value to indicate the information source of your input parameter tolerances. For the moment you may select 2 options:



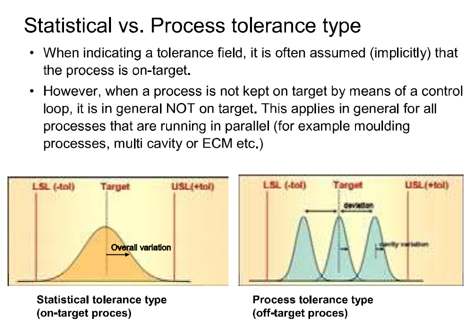
theoretical; based on engineering data/experience for comparable parts, processes or standards like DIN16901 for plastic molded parts.
empirical average, theoretical stdev; average based on limited amount of measurements, stdev based on engineers experience for comparable parts, processes or standards like DIN16901 for plastic molded parts.

2.**Type of tolerance**: indicating the tolerance type of the input parameter.

Statistical: in general this type of tolerance is applicable for a situation in which the input parameter is centered (kept/tuned on target).

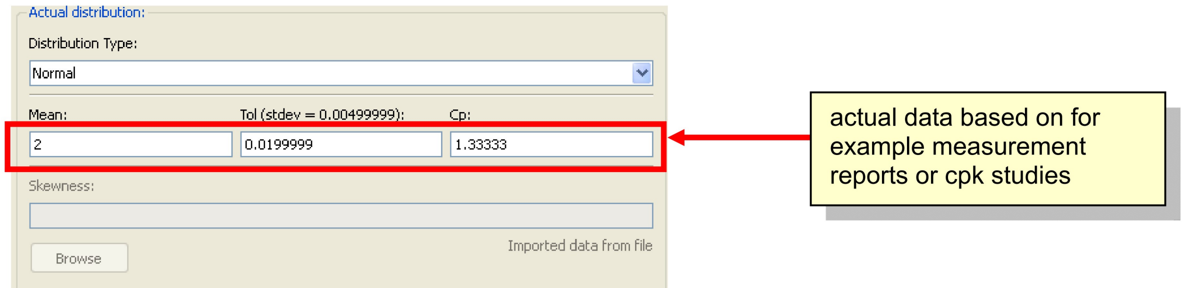


Process: in general this type is applicable for a situation in which the input parameter is typically off-center (not kept or tuned on the target value, but laying somewhere within the tolerance field), for example a dimension of a molded part or a metal part bended by a non adjustable die.



In case the process tolerance type is selected, the deviation of mean has to be entered. It represents the shift from target value (for example the worst cavity of a multiple mould). This value is used in the tolerance calculation as the worst case situation. Default, the deviation of means is set as halve of the single tolerance field. When entering the value for deviation equal to the +/- tolerance value (and setting stdev to 0.000001 (almost zero) you calculate the tolerance analysis with worst-case input parameter, like a traditional worst case tolerance stack-up.

3. **Actual Distribution**: contains the information of the statistical distribution characteristics of the input parameter. These are the actual values of mean and stdev that are used in the capability calculations.



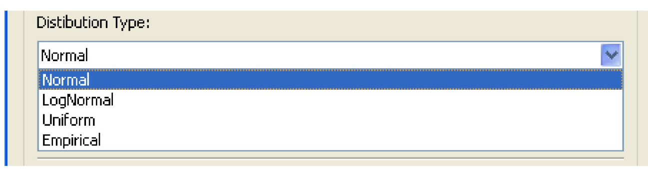
By default the value for Mean and Stdev are calculated from the Target and Tol± value by assuming that Cp equals the default Cp (1.33).

The **Cp** value follows from the equation: $Cp = \dfrac{USL - LSL}{6 * stdev}$.

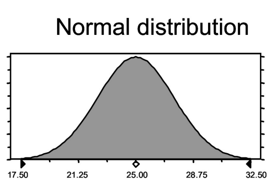
Default the value of mean is equal to the target value and the value of $Stdev = \dfrac{USL - LSL}{8}$ (based on Cp=1.33)

In case the actual Stdev is set smaller, the Cp will be larger then the default, and vice versa. In case of process tolerancing type (for example for a mould), the **Stdev** represents the within-cavity spread.

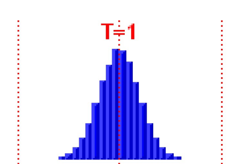
Distribution type: You can select 4 options:



Normal: the normal distribution is the default distribution and is applicable for most cases. The normal distribution is specified by **Mean** and **Stdev** (standard deviation).

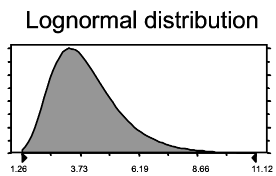


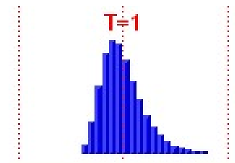
Representation in Tolerance Designer



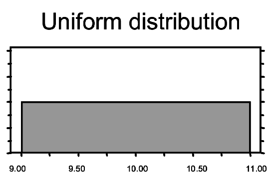
Lognormal: the lognormal distribution can be used in case a skew distribution is expected. The **Skewness** indicates the asymmetry of the distribution. The higher the skewness, the more asymmetric (resulting in a longer tail). In practice, when the histogram of a dataset is asymmetric, you can calculate the skewness with Excel or Minitab or with help of a statistical expert in your organization.

Representation in Tolerance Designer

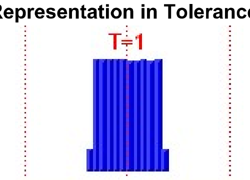




Uniform: the uniform distribution can be used in case it can be expected that a process will deliver all values within the tolerance field in a more or less uniform way. Examples are electronic components that are often binned and the thickness of a grinded part. Due to wear of the grinding tool a new tool will start at the LSL and will be replaced when dimension of the processed parts reach the USL.



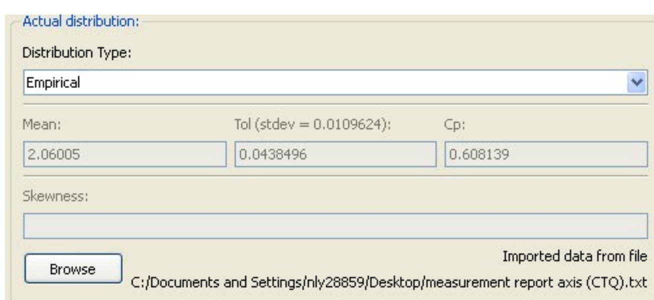
Representation in Tolerance Designer (Cp = 1.33)



By default the generated distribution will be largely within the spec limits, since the default Cp = 1.33. For a uniform distribution in general applies that $Stdev = \frac{\sqrt{(USL - LSL)^2}}{12}$.

Since $Cp = \frac{USL - LSL}{6 * stdev}$ this implies that $Cp = \frac{1}{6 * \sqrt{1/12}}$ or **Cp = 0.57735** will generate a uniform distribution that is just within the full spec limits.

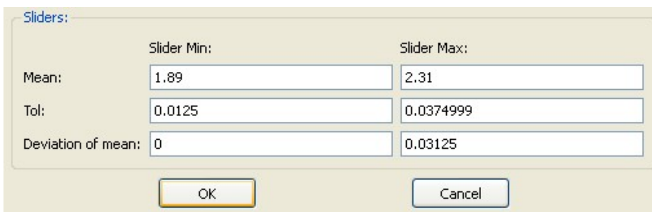
Emperical: this type is not a parametric distribution, but a real data set. It can be used in case the realized dimensions or other parameter values are measured. In case Empirical is selected the **Browse** button is activated to browse the relevant data file (file.txt).



The data file needs to be a .txt file and contain only numerical data of one input parameter (the file may contain text as well). The actual values for Mean, Tol and Cp are calculated based on the imported dataset.

It is possible to switch between the different distribution types during the calculations. In that case, actual values will be reset to default values for the new distribution.

4. **Sliders**: containing information on the slider ranges
The slider fields limit de range for which the values can be varied to calculate the effect on the values of the Output parameters; see Chapter 4 and 5 for more information on optimization of Output parameters capability. Slider fields are defined for **Mean**, **Stdev** and **Deviation of mean**. The latter are only active in case of process tolerancing.



By default the slider range or set as follows:

Mean: **Slider Min** = 0.9*Mean **Slider Max** = 1.1*Mean

Tol: **Slider Min** = 0.5*Tol **Slider Max** = 1.5*Tol

Dev. of mean: **Slider Min** = 0 **Slider Max** = 1.25*Dev. of mean

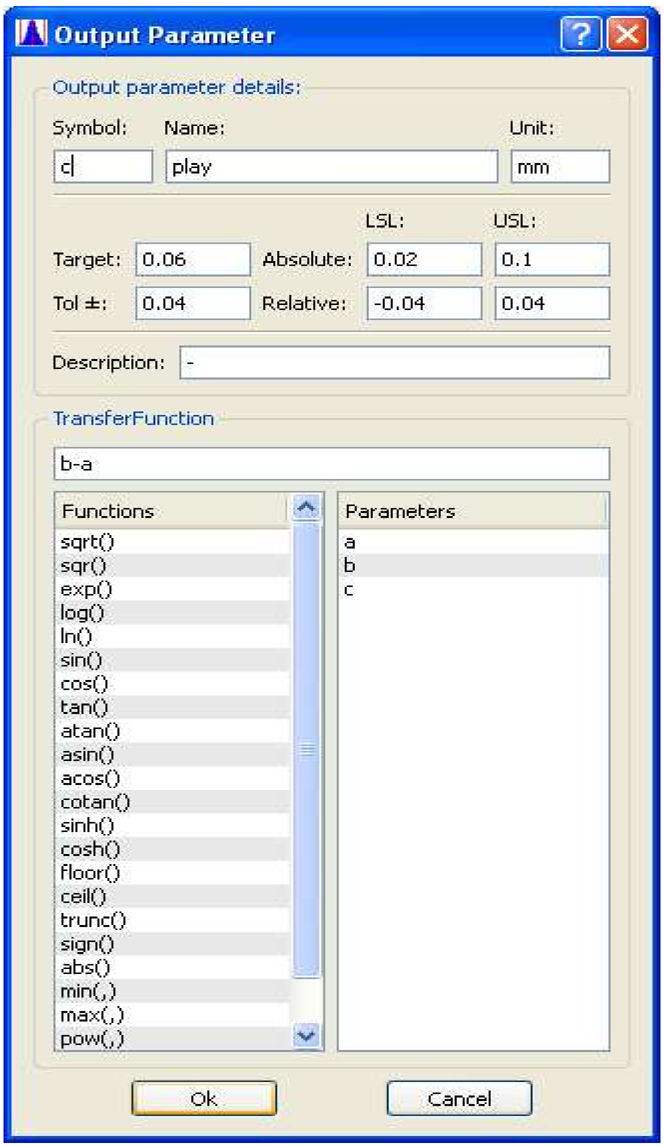
You can adjust the (default) slider range by simply typing another value in the corresponding slider field, in case the default range doesn't cover the range that can be changed in practice (for example Mean: Slider Max = 2*Mean, when you can change the nominal stiffness of a spring in your design with this value).

When you have entered all the relevant information you click <OK> or <Enter>, and the Input parameter is stored in the case file and presented in the summary table on the input tab. In the same way you can enter all the relevant Input parameters, and they will be presented in the summary table.

It is possible to change the settings of an Input parameter later on by double-clicking the line on the **Input** tab after which you will re-enter the **Input Parameter** dialog. This can for example be applicable when the design is changed, or when the first measurement data becomes available in the project. When the design is changed it will most probably reflect in a change (by hand) of **Target, Tol±** values, and the Cp value will be recalculated corresponding to the new LSL, USL values.
When measurement data becomes available it will reflect in a change (by hand) of **Mean, Deviation of mean**, **Tol.** It is compared with the target dimension and tolerance value, and **Cp** value will be recalculated.

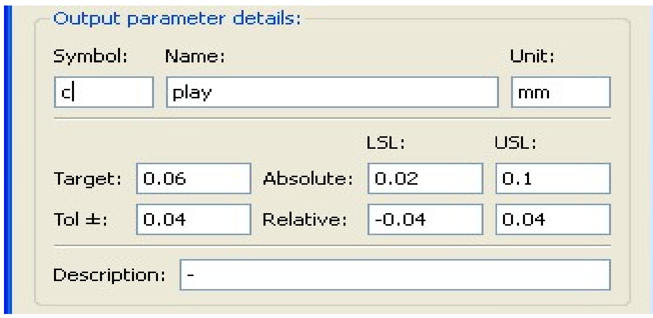
Once the input parameter has been saved, it is still possible to rename it and consequently all the output parameter functions in which the said input parameter is used will be updated automatically.

When entering an output parameter, the following **Output Parameter** dialog pops up.



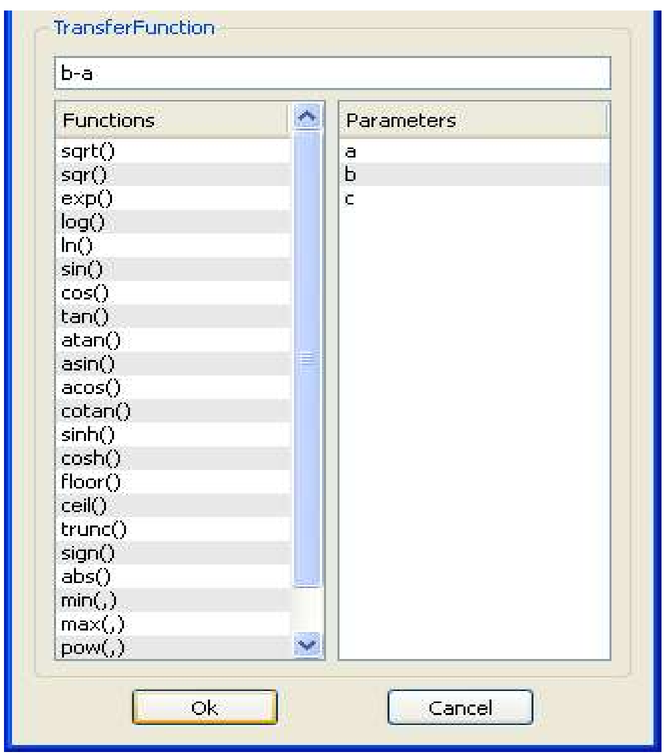
The **Output Parameter** dialog is divided in 2 information group boxes.

1. **Output parameters details**: containing general information of the Output parameter.



You can enter the relevant information on the same way as described for the Input parameter dialog.

2. **TransferFunction**: equation editor block of the Output parameter.

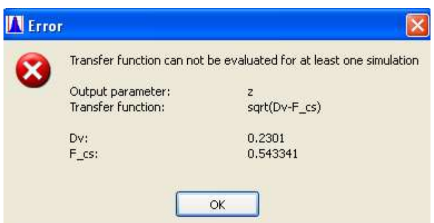


You can enter the transfer function by just typing the equation in the **TransferFunction** field, or using the **Functions** and **Parameters** lists.
The Functions list shows all functions available and you can select the appropriate one by double-clicking it in the list. The selected function will appear in the

TransferFunction field and you can select the relevant Input Parameter from the Parameter list by double-clicking, and so on. It is possible to build a Transfer function Y2 as a function of Input Parameter X1 and Output parameter Y1. In this way the Output Parameter Y1 is an Input Parameter for Y2.

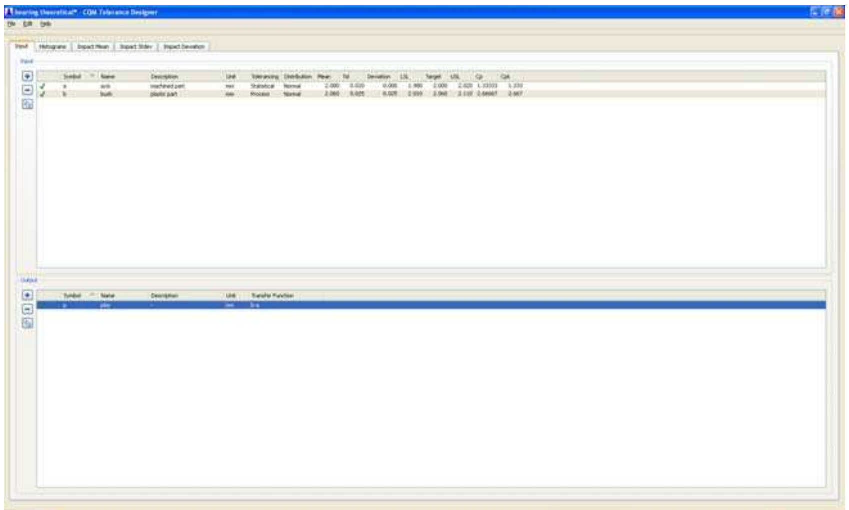
The available mathematical functions are explained in Appendix 2. In case the argument of a mathematical function is not in the range where the function exists or in case you use (accidentally) the Output Parameter it self in the Transfer functon (for example Y2 = Y1 + Y2), an error message will appear at the moment you click <OK> at the Output Parameter dialog.

or a the moment you click the **Histograms** tab



When the Transfer function is completed, you click <OK> or <Enter>, and the Input parameter is stored in the case file and presented in the summary table on the input tab. In the same way you can enter all the relevant Input parameters, and they will be presented in the summary table.

Once the Output parameter has been saved, it is still possible to rename it. This will create a new Output parameter and you have to delete the old one yourself.



By default an ✓ icon is displayed in the first column of a defined parameter, indicating that the parameter is presented on the histograms tab; see Chapter 5 for more information. By clicking on ✓ icon, it will disappear indicating that the parameter is not presented on the histograms tab, and vice versa.

Default the Input and Output parameters are sorted on Symbol (ascending: first by number, then underscore, then letter). However, it is possible as well to sort the list Name, Description, …, Cp by clicking on the corresponding field in the upper bar. Clicking again on the same field will change ascending to descending and vise versa.

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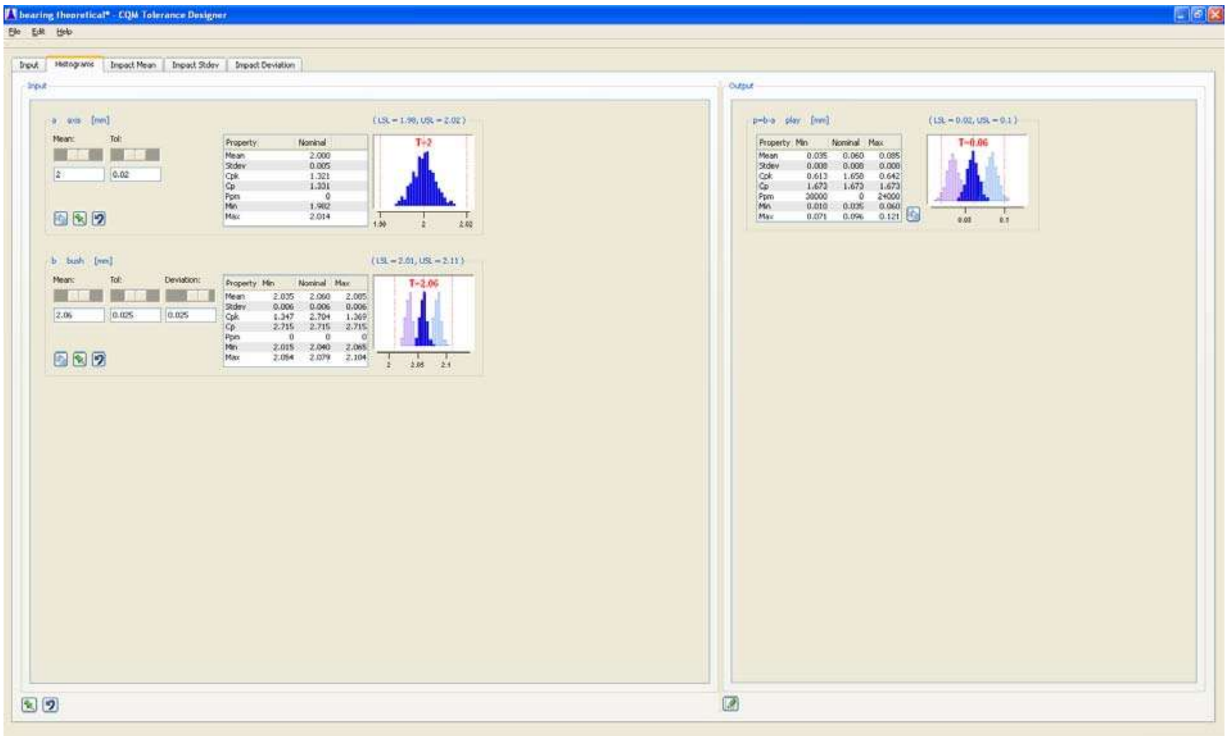
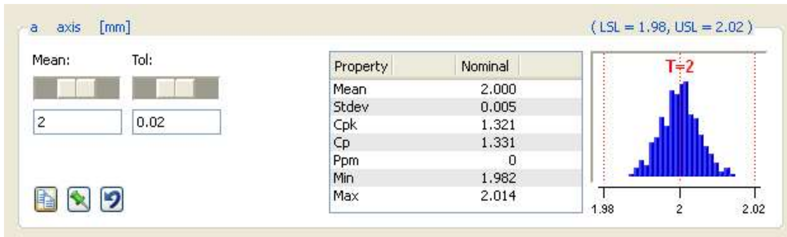
5. Predicting output capabilities

The **Histograms** tab represents the capability summary plots of all the selected input and output parameters. When you switch to the Histograms tab the calculation of capabilities will be executed automatically. In case of many Input parameters (especially when process tolerancing is selected) and/or high number of simulations, this calculation can take some time and as consequently it will take some time before the Histograms tab is visible.

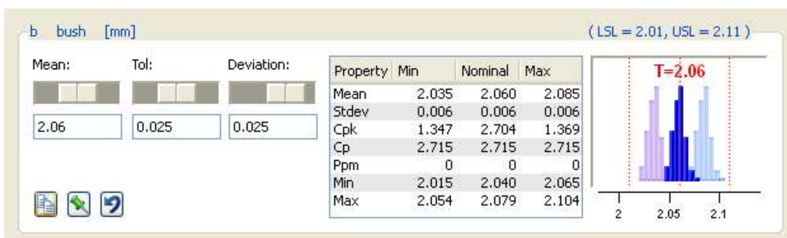


Depending on your screen resolution, the histograms will probably be shown partly and scroll-bars appear. You can change the partition between the Input and the Output blocks (with your left mouse-button like in Windows) to be able to present a full histogram of either Input or Output parameters.

The capability summary plots of Input parameters will be explained briefly. The histogram visualizes the distribution of the input parameter. The dotted red lines indicate the LSL, Target and USL values. For statistical tolerance type only 1 distribution is applicable.



In case of process tolerance type, 3 distributions are plotted. The dark blue one is the nominal case, in which the value of Mean is on target (Deviation of Mean = 0). The other ones are the worst case situations, in which the values of Mean are off target (deviation of Mean = max), where the light-purple distribution is the min and the light-blue is the max situation.



In the middle a summary box of quantitative characteristics is presented; see Appendix 1 for explanation. For process tolerance type, the characteristics are presented for Nominal, Min and Max situation.

At the left the sliders are shown, including their current value. You can change the value of each slider, in order to calculate the effect on the Output parameters of interest. This calculation, including update of the summary capability plots, is executed immediately after you changed a slider value.

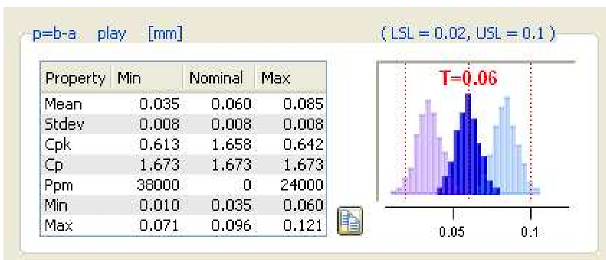
Changing the value of the slider can be done by either dragging the slider itself with your left mouse-button, rolling your mouse scroll-button at the slider, or by selecting the slider value field with your mouse and then typing the value in the field itself.

Dragging with the sliders to investigate the effect of changed Input parameter settings is “free playing” in such a way that these changed values will not directly be stored in the input-parameter. When (after some playing) you have not reached a better capability of the Output parameter of interest or for any other reason want to return to the original setting, you click on the button. When you have reached a better capability of the Output parameter of interest and want to store that setting, you click on the button (once double clicking on the Input parameter line on the Summary table of the Input tab, the Input Parameter dialog will pop-up and you see that the stored settings are now shown in the Actual distribution block).

As in the way you can you reset or store the settings per Input parameter, it is also possible to do so for all Input Parameters at once by clicking on the and the button at the left-under position of the Input Parameters block.

When dragging a slider, the scale of the histogram axis will change to stay suitable for the current range of the values in the histogram. Sometimes you might prefer to fix the axis so that the histogram becomes visibly narrower or wider when dragging the slider. You can fix and unfix the scale of the axis by double-clicking on a line of the summary box in the middle

The capability summary plots of Output parameters are similar to those of the Input parameters, but (of course) without the sliders.



Property	Min	Nominal	Max
Mean	0.035	0.060	0.085
Stdev	0.008	0.008	0.008
Cpk	0.613	1.658	0.642
Cp	1.673	1.673	1.673
Ppm	38000	0	24000
Min	0.010	0.035	0.060
Max	0.071	0.096	0.121

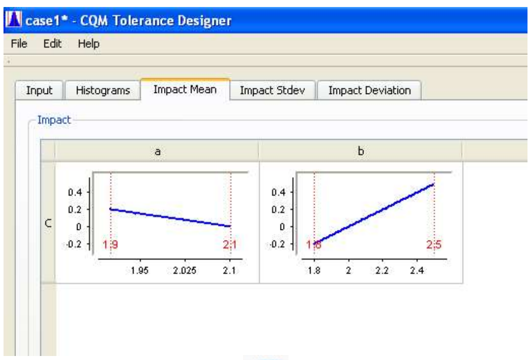
In case at least one Input Parameter with Process Tolerance is used in an Output Parameter, the histogram and statistical characteristics will be shown for nominal and worst case situations. If the mouse hovers over the histogram a tooltip is displayed showing the values of the input parameters corresponding to the worst case situations.

It is possible to store the calculated values of the Input and Output parameters in a file.txt, to use it as Input Parameter data in another case file or just to export it to another software package like Excel or Minitab for any purpose. Each parameter is stored in a specific file which is located in the same directory as the case file itself. For example:

6. Design optimization

The Tolerance Designer contains three tabs that are helpful to optimize your design.

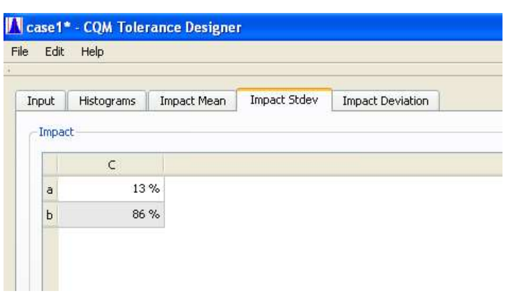
By clicking on the **Impact Mean** tab you enter the Impact of Means shift table. It represents for each Input Parameter (presented at the horizontal axis; a and b in this example) the contribution of a shift of the mean value (within the slider range) to the mean value of the Output parameter (presented at the vertical axis; c in this example). The steeper the slope of the curve, the higher the contribution is. In fact, it can help you to optimize the Cp/Cpk value of an Output parameter.



Note: the copy button work as follows for the Impact Mean tab:

- when just entered the tab it will copy the complete table of impact figures to your clipboard
- when selected a figure in the tab it will copy only the selected figure to your clipboard

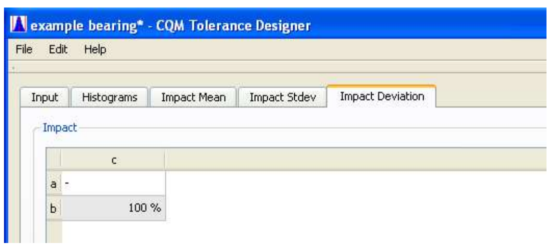
By clicking on the **Impact Stdev** tab you enter the Impact of Standard deviation table. It represents the contribution of the standard deviation of each Input Parameter to the variation of each Output parameter. In fact, it can help you to optimize the Cp/Cpk value of an Output parameter.



For the process tolerance type (see chapter 4), the total variation of an input parameter is split-up between deviation and standard deviation.
The contribution% is calculated based on the standard deviation value.
In case the standard deviation is small compared to the deviation, the calculated contribution% will be small. However the effect of deviation (= shift of mean value)

must also be considered for the total impact of the input parameter. ***Note: When using process tolerance type, be careful with respect to interpretation of contribution% value!***

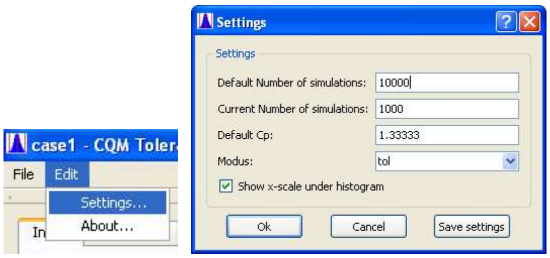
By clicking on the **Impact Deviation** tab you enter the Impact of deviation table. It represents the contribution of the deviation of an Input Parameter (with process tolerance type only) to the Cpk value of each Output parameter. In fact, it can help you to optimize the Cpk_min and/or Cpk_max value of an Output parameter.



All three impact tables give you a clear insight which Input Parameters contribute most, which is helpful for optimization the design. It makes sense to have a look at the impact table before you start investigating at what amount the change of such an Input parameter will change the capability of the Output parameter by means of the sliders on the **Histograms** tab as explained in Chapter 5.

7. Changing default settings

When the input tab is active, it is possible via <Edit> to enter a settings window and change the **Number of simulations, Default Cp** setting for the calculation and the **Modus** for the user-interface of the program.



The **Default Number of simulations** of the Monte Carlo analyses is set n=5000, which is in most cases sufficient and enables fast calculations.
In special cases, where very high accuracy is necessary you can increase n. You can change this setting any time by means of the **Current number of simulations** and the changed setting is stored in your specific case file; see also Appendix 1 for further explanation upon Monte Carlo analyses.

Default Cp = 1.33, this means that Stdev = (USL-LSL)/8 based on standard equation $Stdev = \frac{USL - LSL}{6 * Cp}$. The default Cp is based on the starting point that a process capability Cpk=1.33 requires a (minimum) Cp=1.33. However, when in practice a lower (or higher) Cp corresponds better with the process capability that may be expected from your production/supplier, it is recommended to change the default Cp value before entering all the input parameters.

Default the **Modus** is set as <stdev> which allows you to specify mean values and standard deviations per input parameter which is default with in DfSS. Additionally there is the possibility to switch to <tol> modus. In this modus all the actual values of the input parameters are presented as tolerances, defined as **Tol = 3*defaultCp*Stdev** (for a default Cp = 1.33 this implies that Tol = 4*Stdev). This modus corresponds in a more intuitive manner to the "mechanical engineers language" of applying tolerance bandwidths based on standards and/or previous design drawings and is especially useful to define the theoretical tolerance calculation. It is possible to switch from <tol> modus to <stdev> at any moment.

With the 

button you can store the settings as the default settings of the Tolerance Designer, and they will be used in any case file created onwards.

Appendix A: Explanation of mathematical functions

The following predefined functions are available in the TransferFunction equation editor. We distinguish between functions with one or two arguments.

Predefined functions with a single argument:

- SQRT: Square-root function which can be used as SQRT(X).
- SQR: Square function which can be used as SQR(X).
- EXP: Exponential function which can be used as EXP(X).
- LOG: 10 based log, which can be used as LOG(X).
- LN: natural log, which can be used as LN(X).
- SIN: Sine function which can be used as SIN(X); X is a real-type expression in radians.
- COS: Cosine function which can be used as COS(X); X is a real-type expression in radians.
- TAN: Tangent function which can be used as TAN(X); X is a real-type expression in radians.
- ATAN: ArcTangent function which can be used as ATAN(X).
- ASIN: ArcSinus function which can be used as ASIN(X).
- ACOS: ArcCosinus function which can be used as ACOS(X).
- COTAN: CoTangent which can be used as COTAN(X).
- SINH: Sinus Hyperbolic function which can be used as SINH(X).
- COSH: Cosinus Hyperbolic function which can be used as COSH(X).
- FLOOR: FLOOR(-3.2) = -4, FLOOR(3.2) = 3.
- CEIL: CEIL(-3.2) = 3, CEIL(3.2) = 4.
- TRUNC: Discards the fractional part of a number. e.g. TRUNC(-3.2) is -3, TRUNC(3.2) is 3.
- SIGN: SIGN(X) returns -1 if X<0; +1 if X>0, 0 if X=0.
- ABS: absolute value, which can be used as ABS(X)

Predefined functions with two parameters:

- MIN: MIN(2, 3) is 2.
- MAX: MAX(2, 3) is 3.
- POW: POW(B,P) raises base B to any power P. For fractional exponents or exponents greater than MaxInt, Base must be greater than 0.
- INTPOW: The INTPOW(B,P) function raises base B to an integral power P. INTPOW(2, 3) = 8. Note that result of INTPOW(2, 3.4) = 8 as well.
- LOGN: The LogN function returns the log base N of X. Example: LOGN(10, 100) = 2

Appendix B: Details on Impact Stdev

The impact table is calculated as follows: set the stdev of an input parameter to 0 and see by how much the variation of the output decreases (in terms of % of the variance = stdev^2)

For lineair functions for which the transfer function looks like Y = [expression using only Input Parameter 1] + [expression using only Input Parameter 2 + …. (for example a lineair stack-up to calculate the gap between a number of parts,]) the impact table adds up to 100%. So the percentages straightforward reflect a breakdown of variation of the Input parameters to the Output parameter

As soon as there are interactions or cross terms, such as x1*x2 or tan(x1+x2), the impacts of the Input Parameters of a specific Output Parameter do not necessarily add up to 100%. An extreme example is

- y = x1*x2 (similar to V=I*R, where V=voltage, I=current, R= resistance)
- mean x1 = 0, stdev x1 = 1
- mean x2 = 0, stdev x2 = 1

In this case, y has mean 0 and stdev=1. For the impact of x1, the Tolerance Designer sets the stdev to 0, so that all simulated values of x1 become 0, so all y values become 0 and all variation of y disappears. Therefore, the impact of x1 on y is 100%. Likewise the impact of x2 is 100%.

Impact

	y
x	100 %
x	100 %

.

Note that this is an extreme example. If we change the example to different means

- y = x1*x2
- mean x1 = 2, stdev x1 = 1
- mean x2 = 2, stdev x2 = 1

the situation becomes much less extreme:

Impact

	y
x1	55 %
x2	56 %

.

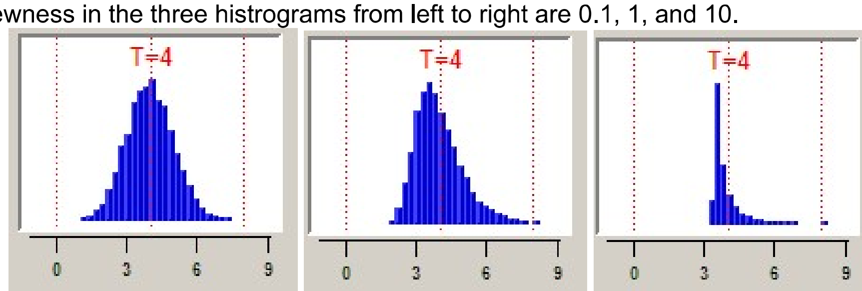
Allthough, the percentages do not add up to 100%, they of course give a meaningfull insight in the contribution of the standard variation of each input variable to the output variable standard deviation and thereby help you to reduce the amount of varation for such an output variable.

Appendix C: Details on the lognormal distribution

Tolerance designer UI
In the tolerance designer, you specify the lognormal distribution by entering

- mean
- standard deviation
- skewness

Here, a small skewness corresponds to an almost normal distribution. In the example below, we have distributions with mean=4 and standard deviation=1. The skewness in the three histrograms from left to right are 0.1, 1, and 10.



Skewness of a given dataset can be calculated in Excel (using the SKEW function, like you would use STDEV and MEAN). You could also choose a skewness by trying a few values until the corresponding histogram shows the desired form.

If the lognormal distribution is specified differently, e.g. in Minitab
In a more mathematical way, a lognormal distribution is specified in a different way than above (mean, standard deviation, skewneess). For instance, in Minitab, it could be given by

```
ML Estimates of Distribution Parameters

Distribution            Location  Shape    Scale  Threshold
3-Parameter Lognormal    1.83984         0.38375   97.76447
```

You can estimate these distribution parameters in Minitab using menu Stat, Quality tools, Individual distribution identification and then specifying 3-Parameter Lognormal. The output above means that the data is described by the following distribution:
Y ~ Threshold + exp(X)
where X is normally distributed with mean=Scale and standard deviation = Location.
So the random variable Y for which we have data availabe, has a distribution
$Y \sim 97.76 + N(0.38375, 1.83984^2)$.

If you specify in Minitab the lognormal instead of the 3-Parameter Lognormal, the Threshold will be set to 0.

Such a distribution has a mean, standard deviation, and skewness given by the following formulas

$$mean(Y) = Threshold + e^{Scale - \frac{Location^2}{2}}$$
$$stdev(Y) = \sqrt{var(Y)}$$
$$var(Y) = \left(e^{Location^2} - 1\right)\left(e^{2Scale + Location^2}\right)$$
$$skewness(Y) = \left(e^{Location^2} + 2\right) \times \mathrm{sqrt}\left(e^{Location^2} - 1\right)$$

The mean, stdev and skewness from these formulas can be used to enter the lognormal distribution into the tolerance designer.

Notes

- The distribution used in the Tolerance designer, and in the Minitab example above is in fact a *shifted lognormal distribution,* in Minitab called the *3-parameter lognormal distribution*. The pure lognormal distribution has Threshold=0. This is the distribution described on the Wikipedia page, which also gives above formulas.
  http://en.wikipedia.org/w/index.php?title=Log-normal_distribution&oldid=333453273
- Distributions in general can have a negative skewness. Lognormal distributions however always have a positive skewness.
- In case you are convinced that your process is tended towards an upper value and therefore is represented best with a negative skewness, you can obtain this in the Tolerance Designer as follows:
  1. define input parameter a with lognormal distrubution using positive skewness (and mean value *-1)
  2. define output parameter b = -a. This new parameter b can be used as an input parameter with a negative skewness

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