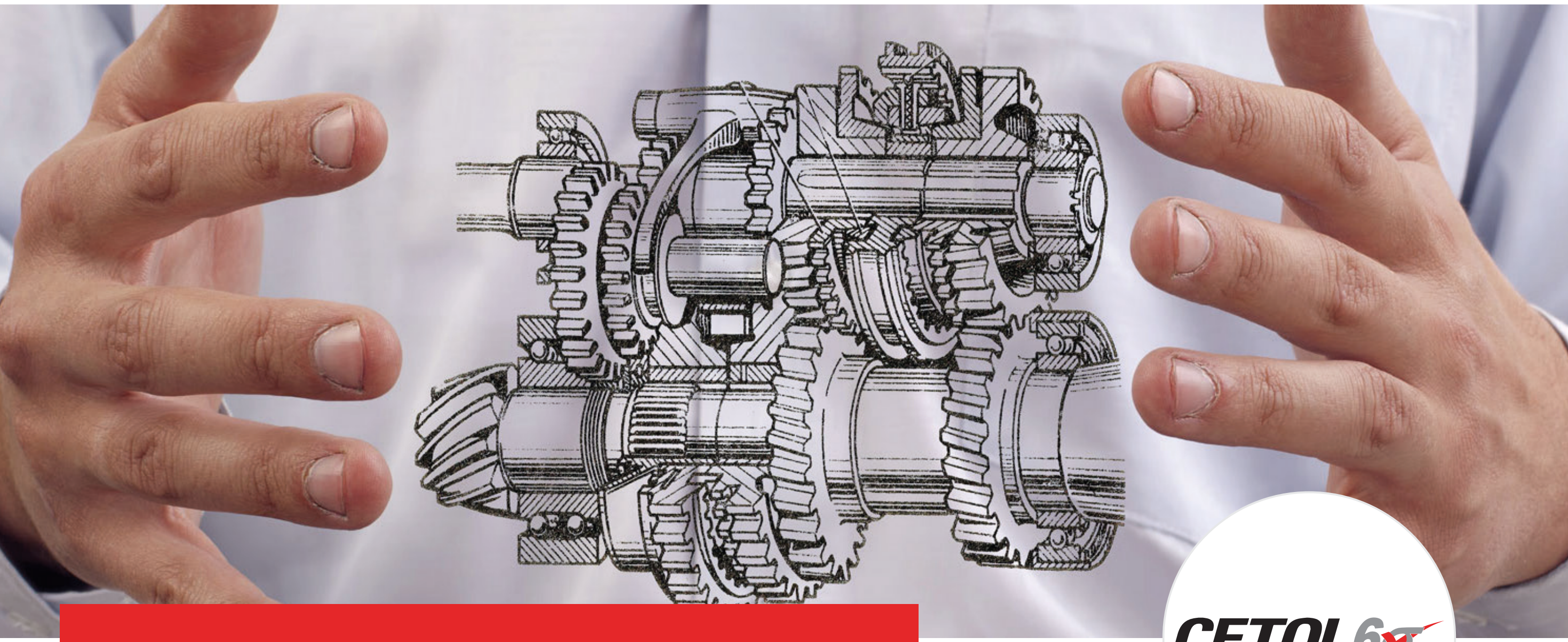


Understanding tolerance stacking: Using CETOL 6σ to improve production quality

by Kwangsu Kim
Tae Sung S&E

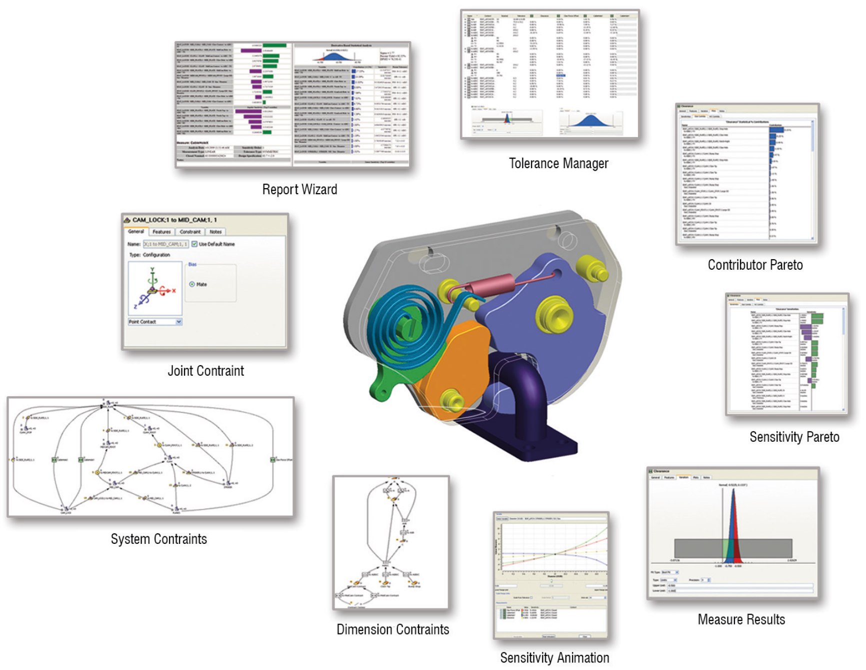
Creating high-quality products starts with the design process where tools such as CAE (computer-aided engineering), SQC (statistical quality control), and SPC (statistical process control) are used to improve the quality of production output.
Once a product has been manufactured, its appearance and function are inspected and its measurements reviewed to ensure that they meet the standards of the drawings at which point a pass/fail decision is made.

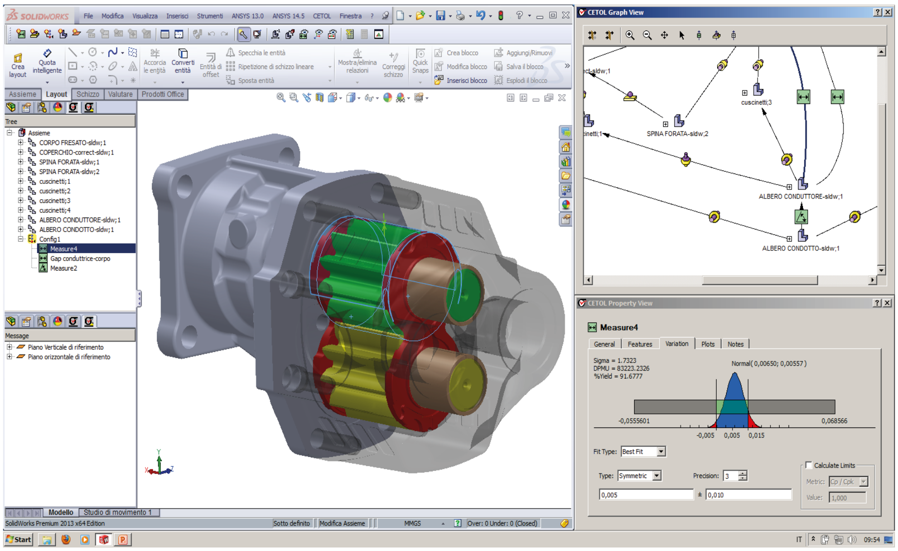
Typically, designers create drawings by considering the order and method of processing, the dimensions and tolerances, as well as the desired performance, assembly process, function, and purpose of the part. Based on the above information, they, consider and apply the appropriate Dimension Chain and Tolerance ranges.
Eventually, once the parts with variations are collected and assembled, the assembly can either be executed normally or not.

To review the correct assembly, a simple model can easily calculate the minimum/maximum intervals.

However, while the cumulative tolerance can easily be calculated, it is not always easy to apply directly to the model in the field. Many aspects have to be considered when applying the cumulative tolerance to a product, namely:

- Which tolerances have the greatest impact on assembly?
- How should the tolerance(s) be adjusted?
- How can the dimensions be adjusted?
- What is the range that can be processed?
- What happens if the design changes?
- Can 1D calculation results be applied to real 3D models?





Key characteristics (KC) and cumulative tolerance

In addition, it is essential to understand the relationship between the key characteristics when calculating the cumulative tolerance. Technical drawings contain a lot of production and assembly information which is not all necessary for calculating the cumulative tolerance.

The term KC [1], widely used in academic circles, refers to “the product, sub assembly, part, and process features that significantly impact the final cost, performance, or safety of a product when the key characteristics vary from nominal” [1].

The calculation of cumulative tolerance analyses for 1D and 2D models is relatively simple. However, most models in the field are 3D for which it is almost impossible to calculate the tolerance analysis manually, so it is necessary to use specialized software, such as CETOL 6σ.

Furthermore, it is not possible to assemble products that are 100% accurate because of deviations in the distribution of product quality during the manufacturing process.

By calculating the cumulative tolerance considering the actual production quality, one can set a suitable tolerance value for the real product rather than a simple theoretical value, with the ultimate goal being to improve quality and reduce costs.

3D cumulative tolerance analysis with CETOL 6σ

CETOL 6σ is feature-rich software that uses the elements of the 3D CAD drawings directly. A relationship model can be easily created simply by selecting elements from the CAD model with the mouse.

As previously explained, the product’s technical drawings contain a lot of information such as processing details, assembly information, inspection features, etc., the KC relationship is constructed and calculated during the cumulative tolerance calculations.

When creating a 3D cumulative tolerance analysis model, the following aspects can be considered for review:

- Order of actual assembly
- Mechanical degrees of freedom
- Quality data

In general, it is advisable to proceed in order, although one can proceed flexibly by changing the order of the two tasks, depending on the model construction method and the engineer’s skill level.

- Objectives (measurements)
- Assembly modeling
- Part Modeling
- Model validation

CETOL 6σ includes the GD&T (geometric dimensioning and tolerancing) standard and if this is not met, the software displays warning messages concerning the errors and omissions in the drawing. This allows the drawing to be inspected and improved, which is essential because the technical drawings can provide valuable supporting material for legal disputes in the event of a problem.

Tolerance analysis is therefore essential in the product development process for improving quality and increasing trust in the company’s products.

Leveraging the results of CETOL 6σ

When the target quality (tolerance range) is applied to the point under review, CETOL 6σ calculates the WC (worst case) result and the dispersion result.

Furthermore, CETOL 6σ also displays the sensitivity and contribution results. The dimensions and tolerances can then be reviewed to improve the product quality.

Sensitivity is used to review the direction and magnitude of the resulting variance when this information is available. Contribution represents the influence (%) of each element when the prerequisite factor used in the

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construction of the tolerance analysis model is 100%. Efficiency can be increased by only including those elements that have a large influence without performing a full inspection of the product.

Using the CETOL 6σ results as a guide, you can review the cost reductions that would result from mitigating those tolerances with a low impact on product quality, which cannot be easily performed in the field.

CETOL 6σ is highlighted on all screens (tree, graph, properties, CAD windows) when a result factor is selected. This is useful from the user's point of view as the model configuration status or enhancement work can be easily seen and used.

Conclusion

Quality issues frequently occur in the field as a result of assembly performance which often causes product functionality problems.

This can create cost and delivery issues, and simply reducing the tolerance size on items does not necessarily improve the product quality or reduce costs.

3D tolerance analysis can improve product quality by examining these issues at near-realistic values.

Tolerance analysis is essential for product development. If you have not yet performed 3D tolerance analysis on the products you develop and produce, it is worth trying.

References

1. Tolerance Analysis: Key Characteristics Identification by Sensitivity Methods", 15th CIRP Conference on Computer Aided Tolerancing, CIRP CAT 2018, pp. 33–38

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What is new in CETOL 6σ ver. 11.3.1

by Enrico Boesso
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Many different and fascinating features have been added in the latest versions of CETOL 6σ, software that allows anyone to perform complex 3D tolerance analyses using statistical variables.

Some new features aim to improve the usability of the software and to make it more user friendly:

Auxiliary features

Users often need geometry for their CETOL 6σ models (e.g. a plane) that does not exist in the CAD model. In previous releases, this required defining the necessary geometry in the CAD model, a procedure that could sometimes be frustrating.

It is now possible to define simple geometry/auxiliary features in CETOL 6σ without having to modify the CAD model. Auxiliary point, auxiliary line, auxiliary plane, auxiliary cylinder, and auxiliary width are all supported.

Auxiliary features can be used as references for measurements, joints, and dimensions just like standard features. In this way it is not necessary to exit the CETOL 6σ environment if a new geometry is required to complete the tolerance analysis calculation model.

Managing ignored messages

Large models often have a long list of messages in the Advisor. After reviewing an information or warning message, you can choose to ignore it from the message context menu to place it in the 'ignored' message list. You can choose "Don't ignore" to return any ignored message to the normal message list

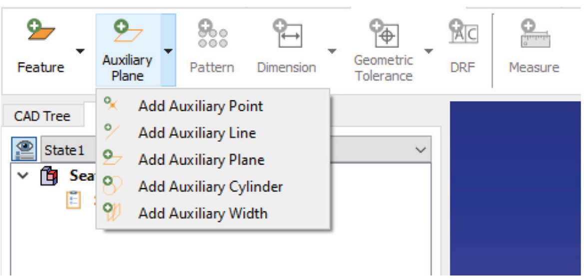
Reporting improvements

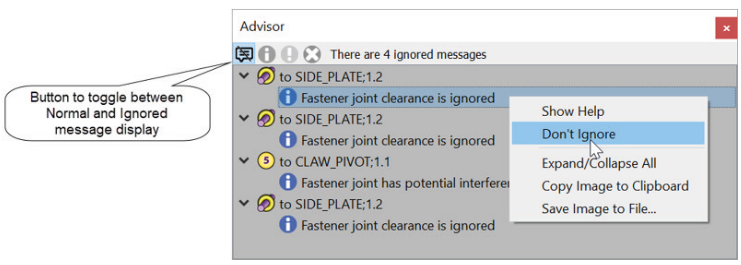
Some minor improvements have been made to the report style sheets. In addition, symbolic tolerance strings are written in the XML of the report. These strings can be included in reports and rendered with the GD&T font Y14.5-2018 (public domain).

Improved Analyzer user interface

The user interface of Analyzer has been modernized:

- A command ribbon has replaced the toolbar.
- Menus have been simplified and reorganized.
- The window layout is improved and more flexible.
- Properties views are consistent with the Modeler user interface.





Other new features speed up the modeling process and maximize the reliability of the output measurements:

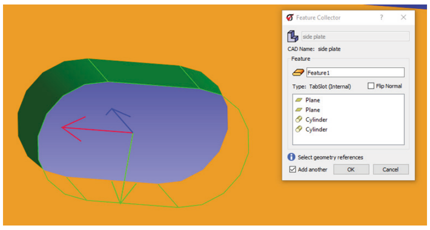
Import CATIA assembly constraints

CATIA assembly constraints can now be imported into the CETOL 6σ model. Options are available to automatically import assembly constraints when adding a component to the model. This option has been available (and much appreciated) for some time in other CAD platforms such as PTC/Creo and Dassult/SOLIDWORKS but is now also available to CATIA users. Users do not have to replicate the definition of mating conditions between parts, which saves considerable time during CETOL 6σ modeling.

Feature Collector improvements

The Feature Collector includes the following enhancements:

- Displays information about the parent part for the selected geometry.
- Continuous Add Feature mode.
- Message indicating what to select.



These enhancements allow users to quickly and easily define complex feature types recursively.

Cross-sectional views

It is possible to define and save cross-sectional views of the CAD model and reuse them later when required.

Floating Joint improvements

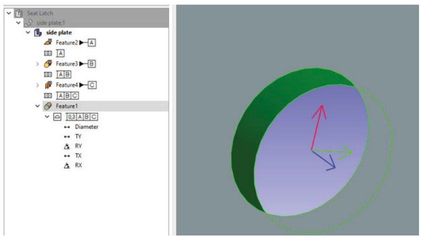
- A single constraint representing float and a better presentation of the float constraint properties showing the joint reference features and their tolerance properties.
- More accurate worst-case analysis for floating joints (i.e. circular, rather than square, worst-case area for flotation between a pin and a hole).

Separate contributions for float are shown for feature variation and joint clearance. Previously all contributions were attributed to the float variables.

There are also some new features to enable the software to behave more closely to GD&T rules:

Improvements to profile tolerance constraints

The implementation of profile tolerance when applied to features of size (FOS) is more closely aligned with the way profile tolerance is described in the ASME and ISO GPS tolerancing standards.



When applying a profile tolerance to Sphere, Cylinder, Cone, Torus, or Arc feature types, the size dimensions are constrained by the profile tolerance, if applicable.

In previous versions of CETOL 6σ, separate independent size dimensions were required for these features. When opening an older model in CETOL 6σ ver. 11.1.0 or later, a message is displayed showing all features affected by this change.

The "Variation Rule Editor" includes a "Tolerance Zone Allocation Controls" option that allows you to specify how the tolerance zone of the profile is allocated between the size variation and the position/orientation variation.

Improvements have also been made to the way limits and distributions are calculated for variables constrained by profile tolerances, resulting in more accurate measurement analyses.

Common Parallel axis references

Common parallel axis references (e.g. B-C) referring to cylindrical or conical features are now supported.

Enhancements to Patterns

There have been a number of improvements related to patterns:

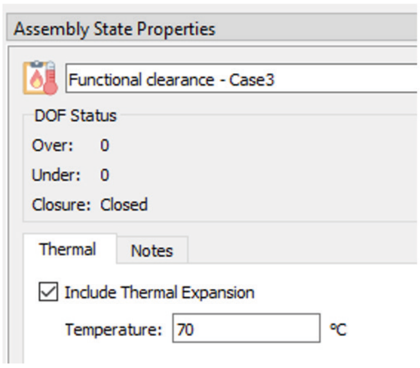
- Coaxial Cylinder Pattern – CETOL 6σ ver. 11.0.0 introduced support for parallel (but not coaxial) cylinder or cone patterns. You can now also add coaxial cylinder patterns.
- Topological constraints to pattern members – A topological constraint can now be defined from an arc feature to a corresponding pattern member (e.g. a cylinder or cone feature).
- Context menu for pattern operations – Many common pattern operations are now available in the context menu of the model tree.
- Pattern member as a datum feature – It is now possible to designate a pattern member as a reference characteristic.

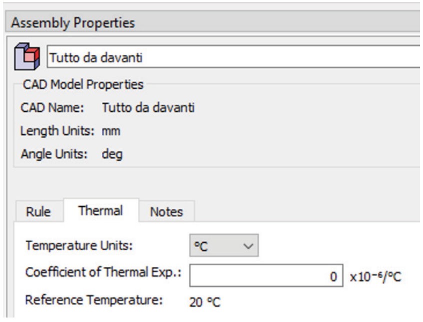
Last but not least, the most important feature to take into account the effect of temperature variations on tolerances chains:

Thermal Expansion

You can now include the effects of thermal expansion in your model:

- Assembly state properties include a Thermal tab where you can indicate the temperature at which to evaluate the assembly.
- Part and Assembly properties include a Thermal tab where you can specify the coefficient of thermal expansion (CTE).





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