The TTT Tapping-Torque-Testsystem as a Multiple Evaluation System for Efficiency Ratings of Lubricants, Tapping Tools and Coatings

"...a window into tribology"

Contents

The TTT System for Comparing Efficiency Rating

Physical Conditions

Substituting all kinds of machining and forming the TTT-System as a multiple system for development and evaluation of lubricants and threading tools employs torque-and process-controlled threading.

Requirements

Just as the lubricant industry depends on the characteristics of the tool and coating, the tool manufacturers depend on the nature and the properties of the lubricant.

Evidence of performance, quality and effectiveness, being used as evaluation parameters, are indispensable.

The measure of all things are the customer's complex production demands. This includes the influence of materials well as cutting speed and many other mutual elements.

Solution

With torque- and temperature-determination the TTT Tapping-Torque-Testsystem, designed as a multiple evaluation system, visualizes a real proof of defining process parameters during forming and machining. By this means predications according to IQ, PQ and OQ* about the performance ability of lubricants, tool-geometries and coatings are possible.

Analysis

In combination with an evaluation software specific features of lubricants and tool structures can be recognized and evaluated. This applies in particular to the complex interactions between formulations and their additives with various work materials and tool coatings in dependence of cutting speed and the temperatures occurred in process. With the integration of an Analyser single measurements as well as series of measurements can straight forwardly be analyzed, evaluated and compared with any reference desired (steps in development / market products).

Performance

From the basic measurement values of torque determination and temperature difference ΔT can clearly be allocated to the factually occurring tribological effects. Appropriate modifications according to the exclusion principle submit exertion of influence.

*IQ Installation Qualification / PQ Performance Qualification / OQ Operation Qualification

TSE Temperature-Sensor-Measurement

Approach

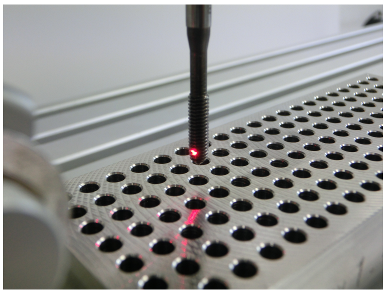
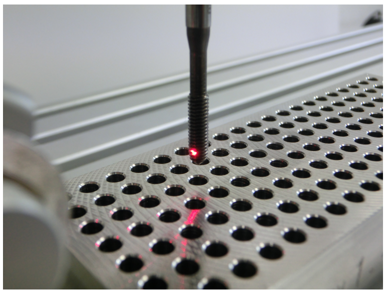
At the time of the greatest heat build-up the exact temperature at the tip of the tool can be measured only with an enormous effort.

Temperature Value ΔT

As a possible solution the temperature value Delta T (ΔT) is computed.

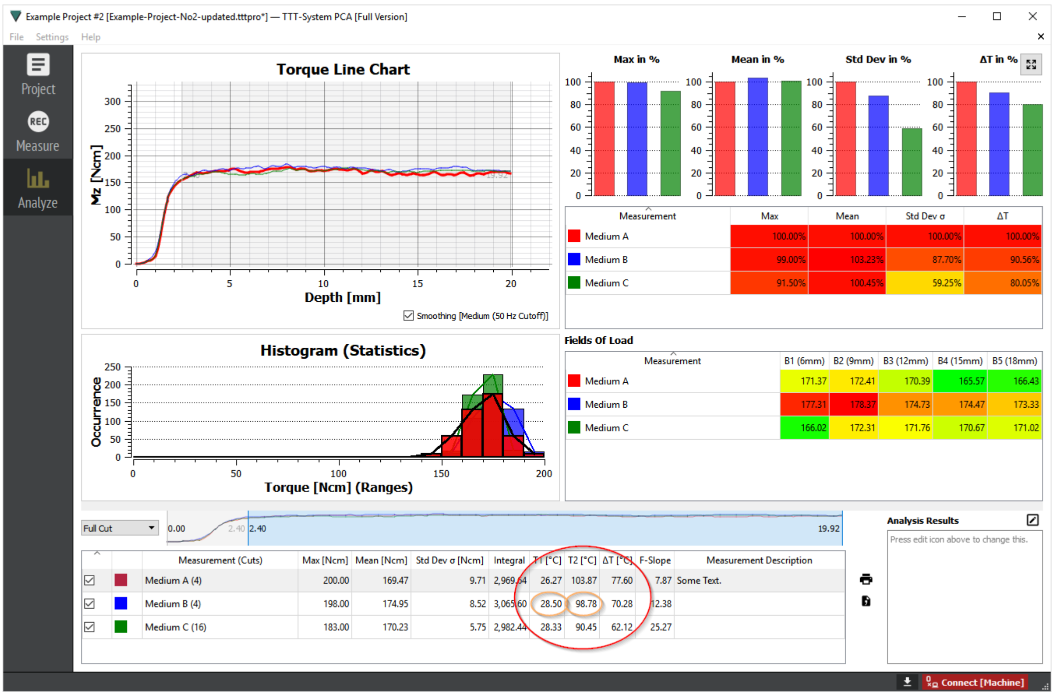
Procedure

Employing infrared thermometry by use of the TSE Temperature-Sensor-Equipment the temperature is determined at the tip of the tool right before measurement...

... and compared with the determined temperature value right after measurement.

The difference results in the temperature value ΔT.



Result

Temperature mean values and ΔT supplemented to torque values of series of measurements.

Torque- and Temperature-Values TTT Standards and TTT Methods

Demand & Coverage of Process-Temperature

With the integration of the TSE Temperature-Sensor-Equipment the temperature value ΔT is added as an additional evaluation factor, to the various values of torque.

Hands-on Performance Evaluation

The TTT Tapping-Torque-Testsystem determines the following values of the torque progression for visualisation of tribological invents*:

1. **Torque** (Mz in Ncm) as a value for the factually generated work performance
2. **Mean Value** (Mz Mean) as a value for the generated work performance in average (arithmetic mean)
3. **Standard Deviation** (Std. Dev.) as a value for the mean deviation of torque around the Mean Value (distribution, synchronisation & homogeneity)
4. **Gaussian-Distribution** / Frequency Distribution as a graphic depiction of the torque values occurred and their distribution as a histogram (Statistics)
5. **Integral** (INT) as a value for the total work load (stress) on the measurement tool
6. **Delta T** (ΔT) as a value for the interpretation of tribological mechanisms*
7. **F-Slope**
   Linear regression of the curve: It is the math. slope of the line between start end end point of the current segment (similar to the old dual cursor). The value is the angle in degrees. The lower, the better.
8. **Fields of Load**
   Torque of several fixed points (depth 6 mm, 9 mm etc.) are visually shown for easier comparison.
   This enables you to quickly see which cut performed better in this section, even if the absolute torque values are close to each other.

The TSE Temperature-Sensor-Equipment determines the starting- and the end-temperature for the calculation of ΔT.

TTT Methods & Standards

In adaption of different TTT Methods (creation of series of measurements) and specified TTT Standards (material** & parameters), controlled, comparable and repeatable results are realized. The therefore developed TTT Methods and fixed TTT Standards consequently applied – according to task –, submit to compare the determined results internally and in different laboratory groups. Each test-bar (of one and the same material) submits 140 faultless measurement results with one installation only.

* At determination of the friction coefficient the physical load parameters in a wear process are defined in four quantities :

- Normal Force FN (Torque)
- Velocity V (Cutting Speed)
- Temperature T (Delta T)
- Fields of Load (tB) (Depth of Thread / Time)
  GFT, Tribologie from 2002, sheet 7, page 8

** For additional information please see “TTT-Measurement-Equipment”

TTT Methods and Evaluation

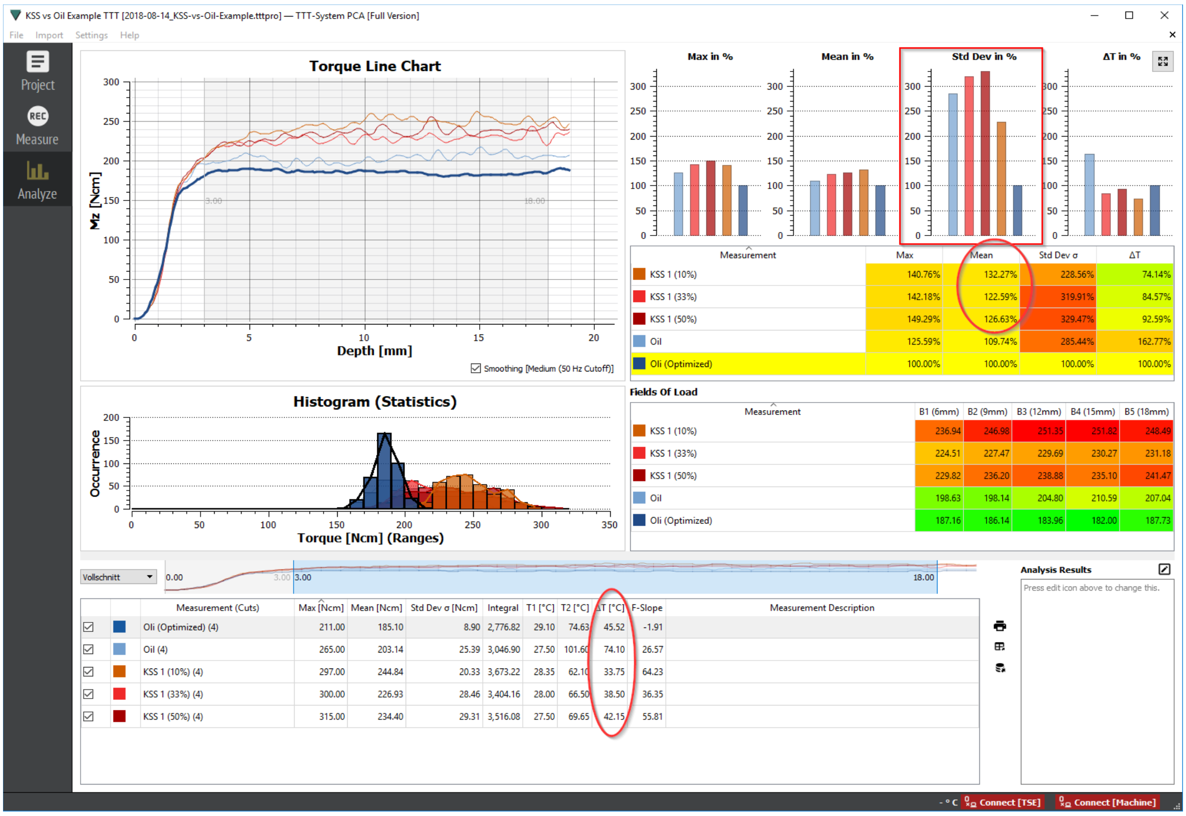
With the application of various TTT Methods (following the so called “Exclusion Principal”), the lubricating mechanisms-of-action of individual formulation-ingredients can be recognized and allocated to specific properties of tool geometries and coatings.

TTT Methods

By using different TTT methods, specific properties of formulations and neat oils and their interactions with different types of tool coatings on the one hand and thread profiles and tool geometries dependent on the process speed on the other hand become transparent and interpretable. They can be systematically influenced with appropriate modifications.

With the computation of the temperature value ΔT we gain adequate information about the cooling capacity of the parts of water and their correlation with other process parameters, e.g. process speed and also the slippage of tool coatings.

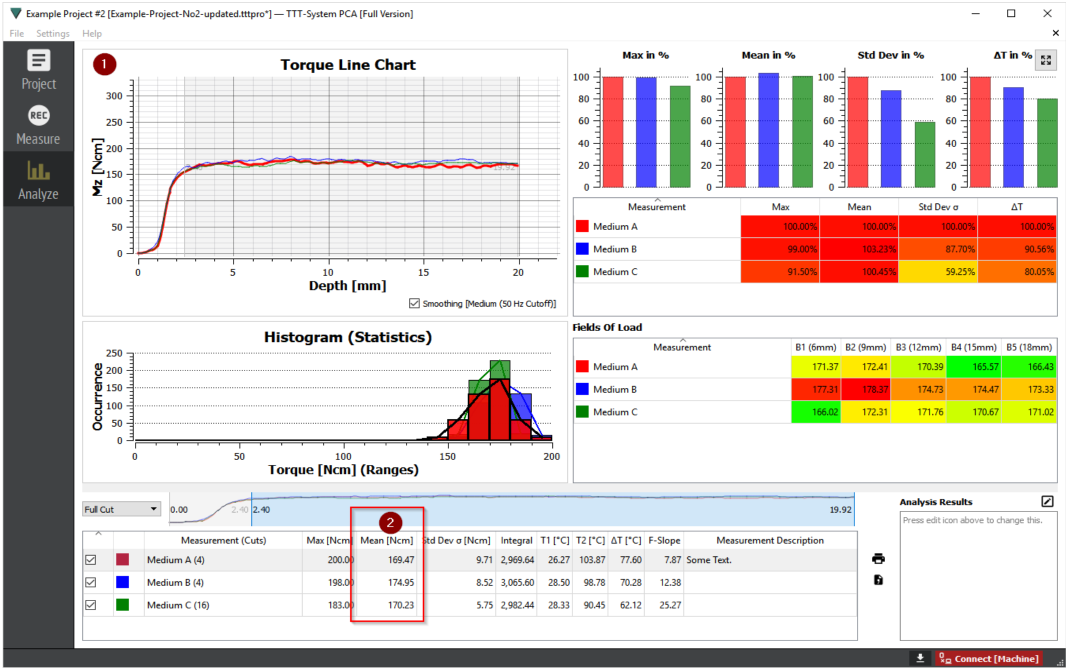
When simultaneously observing torque values, e.g. the Mean Value of the Standard Deviation relating to the parts of water of a MWF, and ΔT, tribological effects become visible.



Analyzer Evaluation

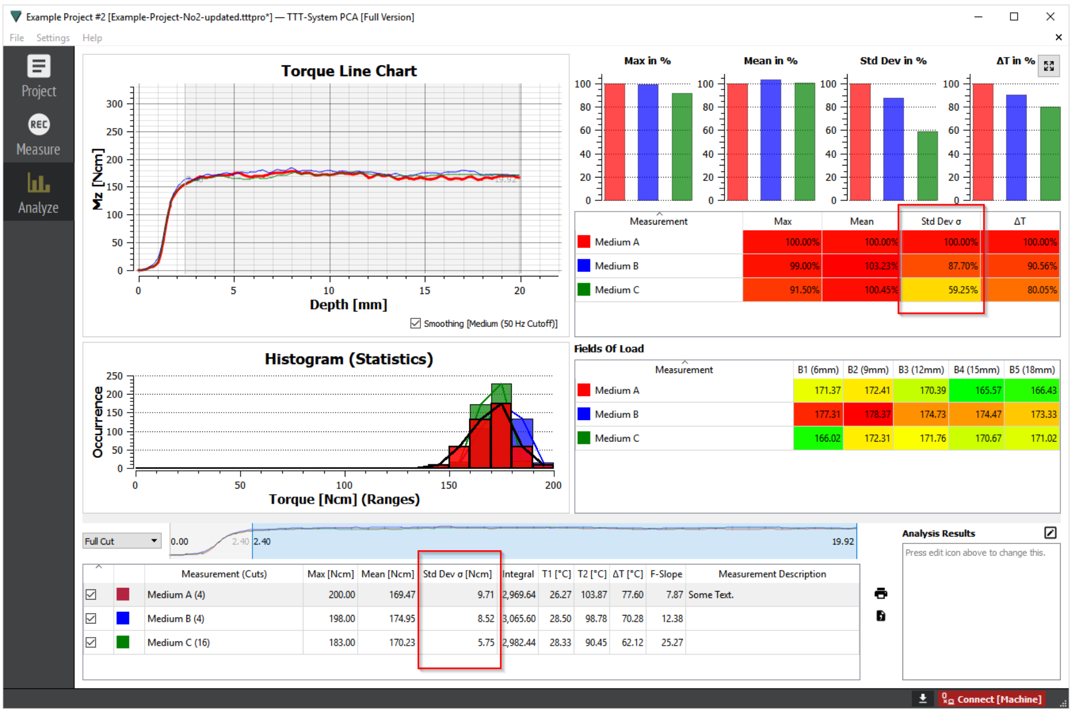
The TTT-System visualizes test results according to the guide lines mentioned above and the determined values there of. The MS Windows compatible Evaluation Software (Windows 7 / Windows 10 (Pro / Enterprise)) submits a practice oriented performance evaluation via integrated analysis for the assessment of all torque and temperature values occurred.

Torque Evaluation-Parameters at a Glance



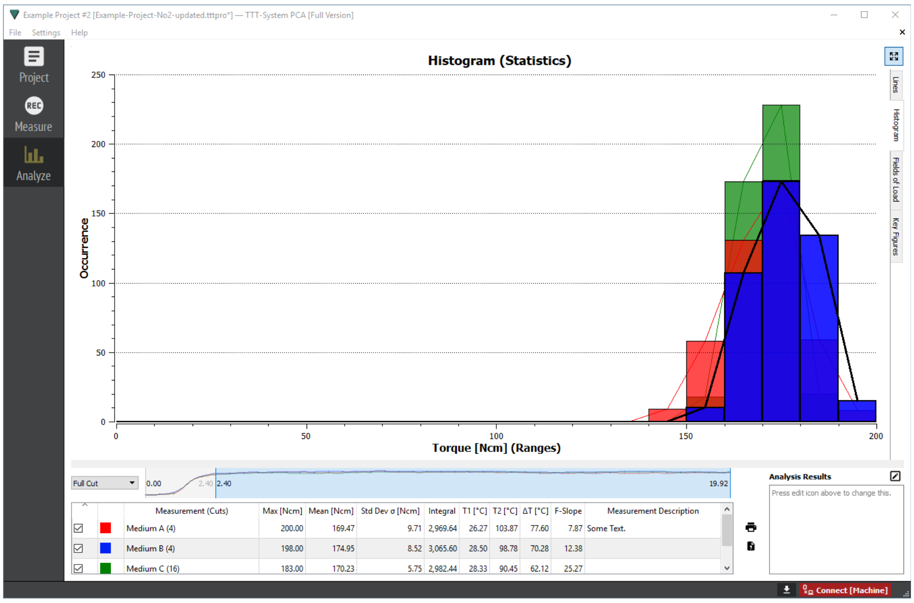
Torque as a value for the work performance (Torque Mz in Ncm)

Mean Value as a value for work performance in average (Mz Mean)

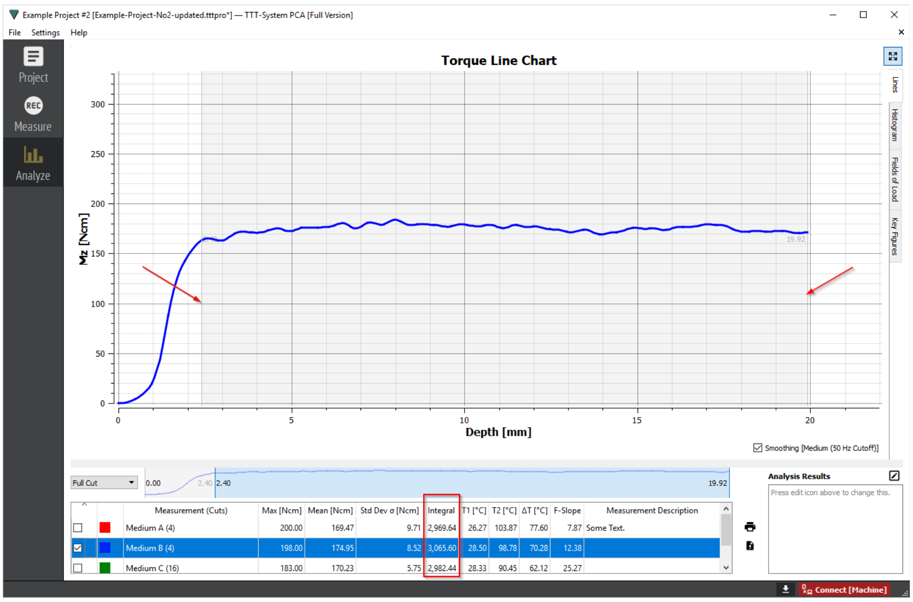


Standard Deviation as a value for the mean deviation of the torque around the Mean Value

Frequency distribution of torque / Statistics and the Integral



Frequency Distribution graphic depiction of the distribution of torques as a histogram (Statistics)



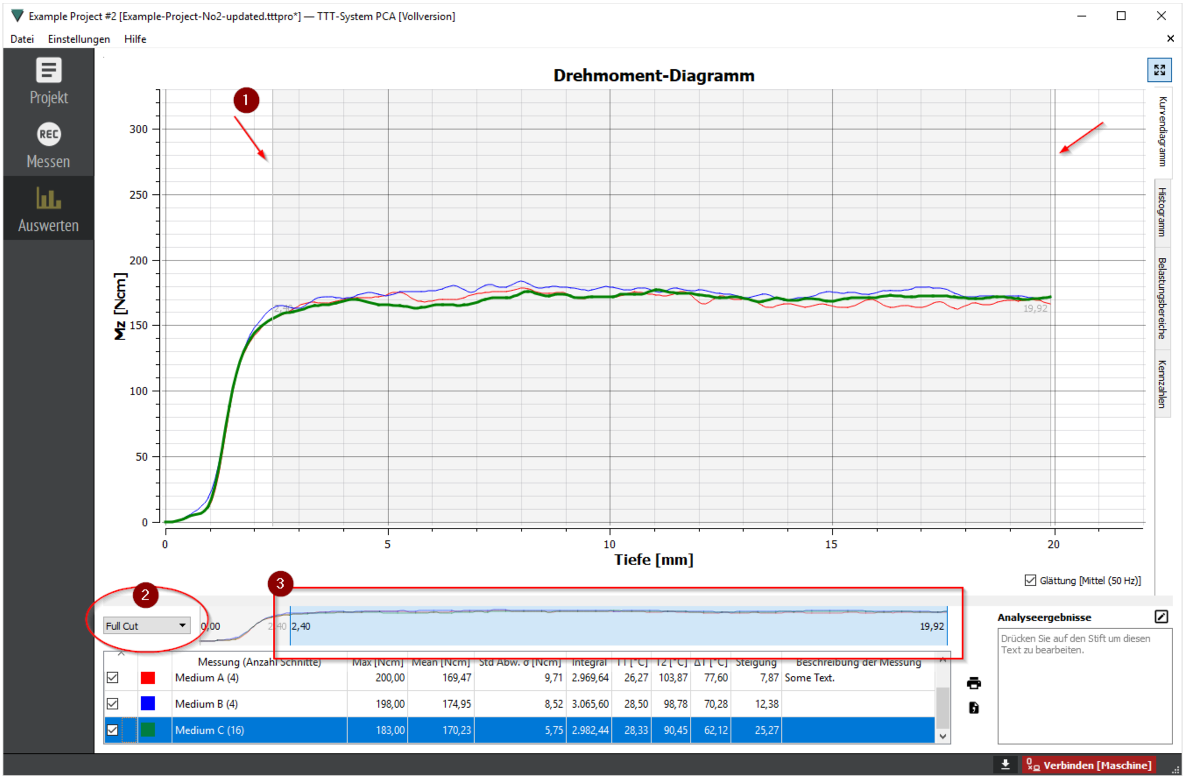
Integral as a value for the total stress (friction) on the measurement tool

With the “Surface Integral” (Trapezoidal Rule) – as an additional feature to the measured values of torque to depth (Mz max. Ncm), Mean Value (Mz Mean) and Standard Deviation (Std. Dev.) –, it is also possible to display and to evaluate the total stress on the tool as an integral-value (è friction / stress / wear).

Overview of PCA Analysis Features

Segments (replaces the„Dual-Cursor“ in WinPCA 3.x)

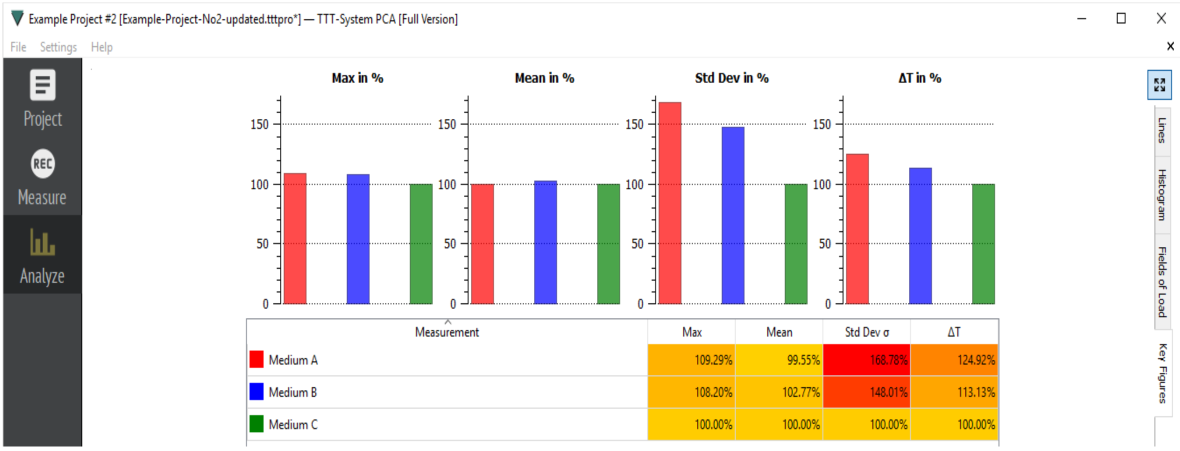
The recorded measurement data can be limited with segments and evaluated over different work or requirement areas. Only the torque data inside of the segment is used in all calculations. Typically there are two segments: Run In and Full Cut.



In the graph, the current segment is highlighted in gray (red arrows ❶). It can be changed left and right at the edges of the blue segment display below the graph (red rectangle ❸). On the left side of the segment representation the active segment is visible which can be changed there (drop-down menu under ❷).

All data of the table or the key figure are ALWAYS valid only for the current segment (this is not true for the temperature **ΔT**).

Key Figure Bar Charts



In the above example the Medium C is set as reference (100%).

The measured values Maximum, Average, Standard Deviation and Delta-T can be compared visually as a bar chart and relative to each other (in percent) using the Key Figures function. This is a central function of the "Evaluate" mode (similar to the WinPCA 3.x "Analyzer" function).

New visualization: Fields of Load

Torque of several fixed points (depth 6 mm, 9 mm etc.) are visually shown for easier comparison. This enables you to quickly see which cut performed better in this section, even if the absolute torque values are close to each other.

Measurement	B1 (6mm)	B2 (9mm)	B3 (12mm)	B4 (15mm)	B5 (18mm)
Medium A	171.37	172.41	170.39	165.57	166.43
Medium B	177.31	178.37	174.73	174.47	173.33
Medium C	166.02	172.31	171.76	170.67	171.02

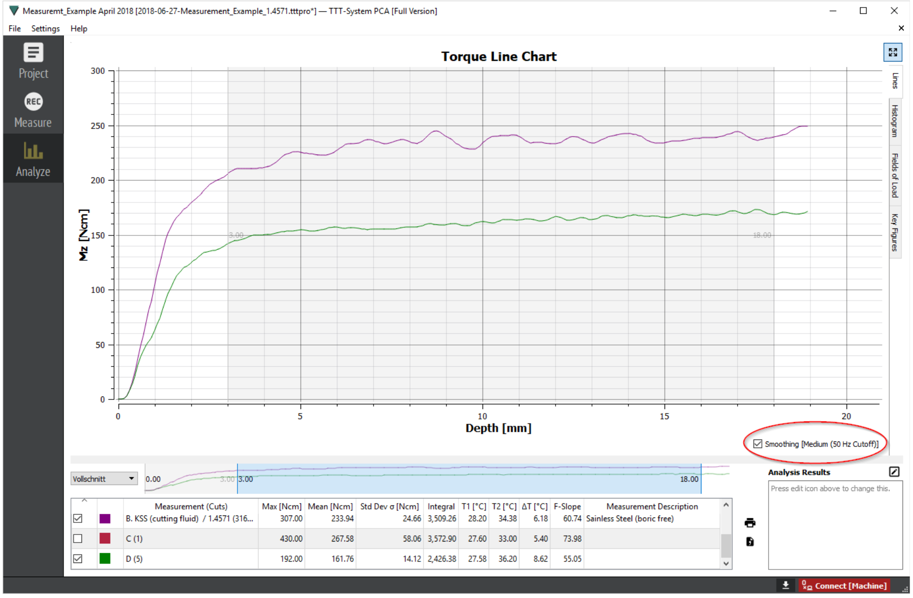
Tribological Example

Medium A has a lower torque (Mz) at depths B4 and B5 (see illustration above) than at depths B1 to B3, from which it can be deduced that the medium A has better lubricity (performance) at depths B4, B5 and the resulting higher requirements due to friction and temperature. Medium B shows a similar behavior but overall is worse. Medium C shows a contrary behavior.

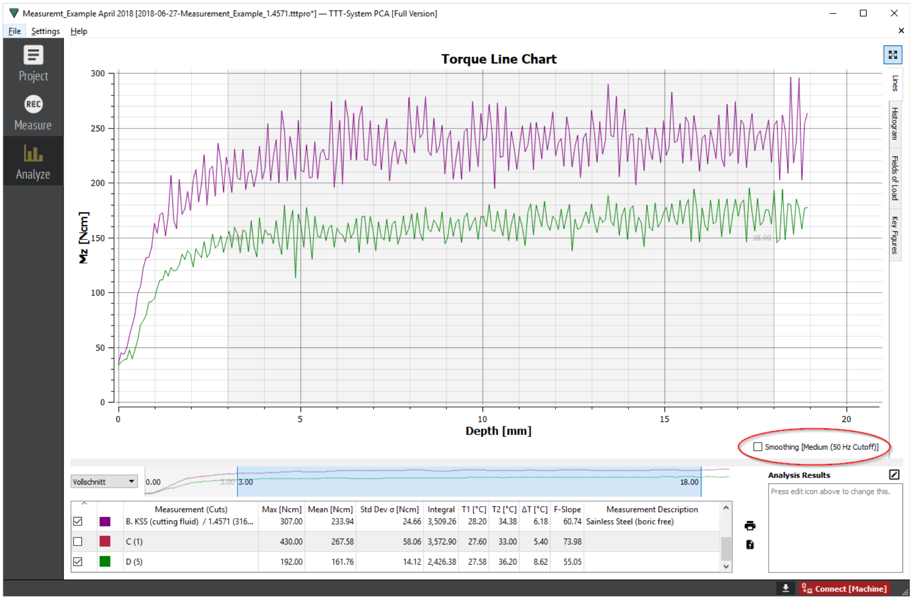
It can be assumed that due to the temperature-dependent effect of additives and so-called EP's, the formulator has a tool at his hands which, according to the "exclusion principle", can be used to proof the efficiency and effectiveness of every ingredients, practically like on the filed.

Smoothing of Line Graph

The function “Graph-Smoothing” provides a flexible and application-oriented observation between raw data and smoothing.



The function-button (On/Off) in the register „Graph“ provides a fast switch of the depiction to the unsmoothed raw data (Graph Smoothing).



The TTT-System as a Laboratory-Complete-System with Integrated X-Y-Positioning Table MPT

Start and Handling-Functions

Start functions of the X-Y Manual-Positioning-Table MPT

- Function-start with automatic fixation of position (setting ex works)
- Start und deadlock at release of multifunction handle
- Using the motor-stop-function, start with foot switch or start lever

Properties / Features

- Electromagnetic fixation for manual positioning of work piece, precise & quick
- Electromagnetic fixation not before tap point is reached
- Smooth-running cross-roller bearings realize centering with tapping tool

Advantages

- The various start functions as mentioned above provide selection of the specific mode, with which a user realizes secure and precise measurement results
- Smart, quick and aligned positioning of work piece and accurate centring at the same time

Benefits

- Threads, unaligned, tilted and cut or formed across are avoided
- Measurement mistakes caused by unaligned centering are avoided
- Efficient, quick and precise production of high-grade threads / series of measurements and effective laboratory results

General PCA Applications

Synchronization Joint Laboratories

- All measurement-data parameter-settings can be stored and recalled for project-related or further use, e.g. securing repeatable guidelines for generation of measurements series, notably for synchronization in participating joint laboratories
- Specific measurement series Parameter set and project configuration as well as operating values (test material and tool) are stored in the project.
- Simple compilation of measurements (SumCut) for analytical and comparative evaluation
- Clear color division (colors freely selectable by the user) improves the allocation of products and the representation of graphs and analysis
- Clear presentation of key figures as bar charts
- Percentage allocation of all key figures for efficient comparison, e.g. with a reference, individual product and development steps and/or market and competitor products

Software Optimization

- Project management with all settings (machine parameters, operating values (tool, workpiece), all cuts)
- Automatic generation of an average value of a measurement series
- Color assignment of different products (colors can be adapted), lubrication media and/or tools and/or coatings
- Project-related entry of information and/or evaluation results
- Optional integration of the return behavior

Calculation Formula and Method of PCA

Measurement Formula

Torque measurements are compared acc. to process quality control and values displayed on the screen as a graph, with applied torque shown as a bar chart. The formulas used to find the Mean and the Standard Deviation are as follows:

Average (Mean Value) = $\sum_{i=0}^{n-1} x_i / n$ StDev = $\sqrt{\sum_{i=0}^{n-1} [x_i - ave]^2 / n}$

Mean Value / Arithmetic method
The expression is called arithmetic methods of n sizes

$$„ a_1, a_2 \cdots\cdots, a_n \quad \chi_A = \frac{a_1 + a_2 + \cdots\cdots + a_n}{n} = \sum_{k=1}^{n} a_k “$$

For two sizes a and b = $„ \chi_A = \frac{a+b}{2} “$

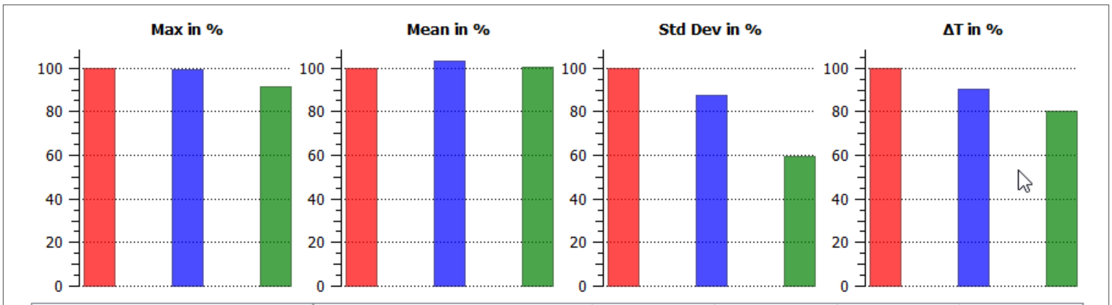
Area Calculation in Detail

The “Trapezoidal Rule“ describes the mathematical procedure of numerically approximating the integral of a function f (x) in the interval [a, b] (numerical squaring). That means to substitute the area below the curvature with the maximum number of trapezes of all possible sizes.

The sum of all trapeze-areas (∑ A) A = $\frac{a+b}{2}$ x h gives a value, which we enlist as a ratio for friction.

Key Figure Comparison

The tabular evaluations show the difference (within the current segment) of three measurements depicting the Mean, Max and Std Dev (standard deviation) as well as Delta-T values in relation to reference (100 % / yellow).



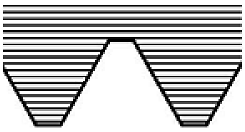
Measurement	Max	Mean	Std Dev σ	ΔT
Medium A	100.00%	100.00%	100.00%	100.00%
Medium B	99.00%	103.23%	87.70%	90.56%
Medium C	91.50%	100.45%	59.25%	80.05%

TTT Methods (Thread Forming and Cutting)

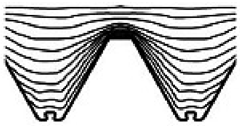
Thread Forming

Thread forming has acquitted itself well as a standard measurement procedure in proof of effectiveness of lubricants.

When cutting threads (substitution for machining), in contrast to forming threads (substitution for forming) lesser torque is required.



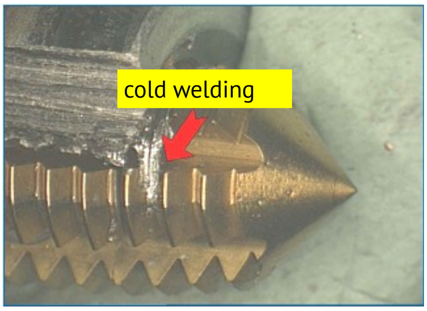
Fibre course at thread-cutting

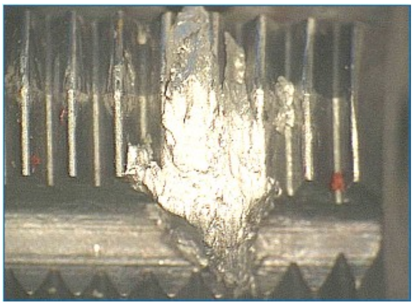


FFibre course at thread-forming

Comparison of Thread Types

In comparing measurement values of thread forming and thread cutting (lesser torque) the functionality for high und low friction can be evaluated.





Cold Fusion

Cold fusion arises when the lubrication film is interrupted and the interacting surfaces go into fusion. In such a case the measurement tool is badly damaged and actually ruined.

Surface

When testing with a magnifier or a digital microscope even a layman can easily recognize the bad state respectively the wear of the tool (the digital-microscope is an option of the TTT System).

Built-Up-Edge

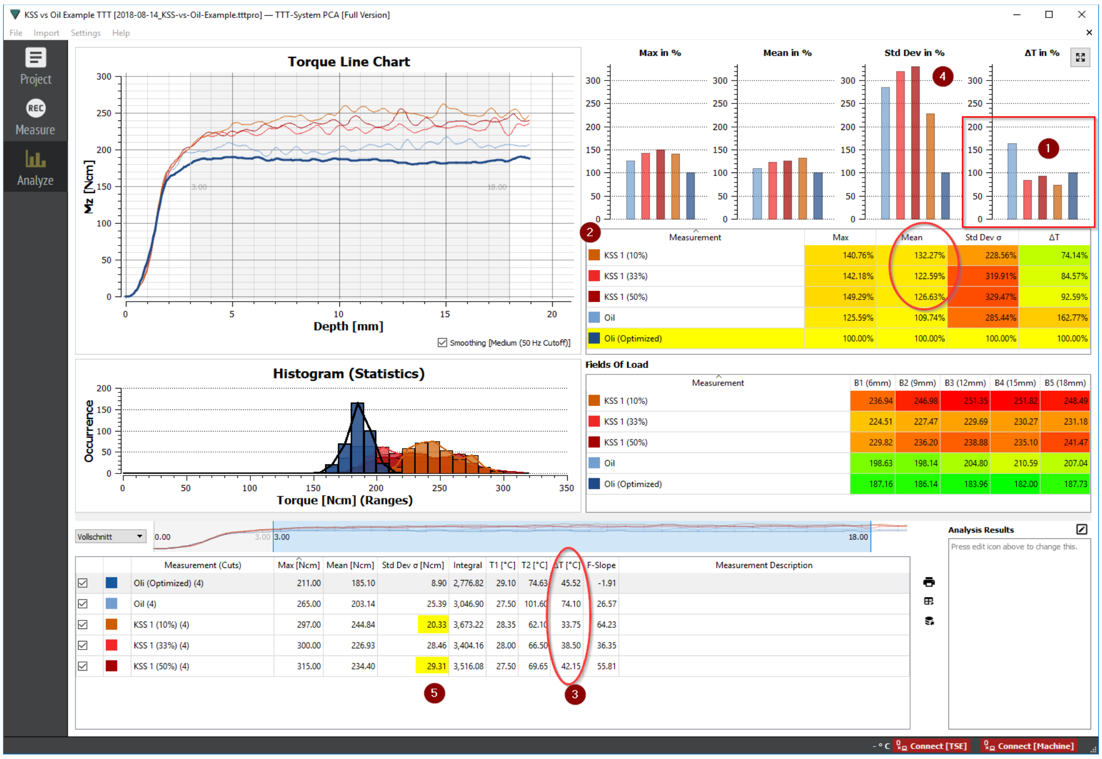
Also a built-up-edge (or break-outs) can likewise be recognized at the measurement tool with a microscope / magnifier.

For optimized assessment of the thread surface the thread should be cut open and thoroughly examined with a microscope.

Performance Comparison Neat Oils and Cooling Lubricants

Practical Example

We compare the functionality of neat oils in direct practical comparison with water-miscible cooling lubricants using stainless steel X6CrNiMoTi17-12-2 (V4A / 1.4571 / 316Ti) for thread forming with M4 at 800 rpm and 20 mm depth.



Results and Analysis

Red, **light red** and **orange** in the bar chart ❶ are three cooling lubricant emulsions. **Dark blue** and **light blue** are each a cutting oil for stainless steel, whereby the dark blue represents an optimization, which was further developed from light blue to meet customer requirements. The example shows the differences and improvements can very clear. In the above picture, the **dark blue** product is set as reference (100 %).

In the tabular evaluation ❷ it becomes clear that the three cooling lubricants perform worse over maximum, mean value and standard deviation, here marked red/orange. The optimized cutting oil is used as the reference (yellow / 100 %). The optimization between the oils is particularly noticeable in the ΔT value.

The comparison of the coolant concentrations, here 50 % (dark red) and 33 % (light red) as well as 10 % (orange) on the right in the bar chart clearly shows the "effect" of the higher water content (90 %) in the ΔT value ❶ ❸ - but also the higher standard deviation in the value of 29.31 vs. 20.33 (coolant 1 with 10 %) ❹ ❺.

In comparison, the coolant **dark red**, **light red** and **orange** are worse than the pure lubricating oils, **dark** (the optimized cutting oil variant) and **light blue** in all parameters compared to both cutting oils. However, the cooling capacity of the cooling lubricant is clearly visible.

TTT Methods , Know-How and Outlook

Carry-Over Effect

A common problem in dynamic measuring of lubricants is the so-called “Carry-over-Effect” which occurs when several series of measurements (with different lubricants) are (to be) performed with the same tool.

Here we talk about the carry-over respectively the transfer of chemically self-acting additives (surface-active substances) via tool from one lubricant into the other. Attention should be paid to the thereof resulting mechanism of action when in combination with certain temperatures (!) surface-active additives form so-called reaction layers during process, for example FeS (iron sulphides, pyrites). These layers may alter the crystalline structure of surfaces, change the electronic setting locally and enlarge the surface. Here it has to be assumed that (at least) in the moment of functioning they do not sit on top of the surface – as often is read in books – but rather generate a new surface themselves. Therefore it may not be possible to remove the residues of these additives from the tool with agents like gasoline, acetone and air pressure.

TTT Methods

The destination was to avoid such falsification. With a specially developed TTT Method the carry-over effect can be discovered. The possible results may actually lead to new insights.

Measurement Tool-Compensation

With another TTT Method we additionally realize a compensation of tool wear in series of comparing measurements of a variety of lubricants with one tool only. That goes along with a significant cost reduction for measurement tools.

Integration of Customer-Logos

It is possible to change the logo to brand the evaluations. Without any external software.

Outlook

In close cooperation with TTT Customers we intensely and progressively engage in enhancing the TTT System and appreciate any kind of cooperation and suggestion.

If you have questions, please send an email to support@microtap.de.

We are looking forward to assist you as quickly as possible.

Last not least here you find our TTT-Video for your kind attention.

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