Find the right gauge for monitoring your process: Methods of measurement system analysis

Have you ever wondered whether your gauge is suitable for monitoring your process? The answer is measuring system analysis. In this article, I will give you a short overview of the most relevant terminology and an introduction to the typical methods illustrated by the measurement of an adhesive agent coating on torsional vibration dampers.

Torsional vibration dampers protect the power train in combustion engines from peak loads that occur during the shock-like transmission of forces from the pistons to the crankshaft. They consist of a metal hub and a flywheel ring connected by a rubber element. The rubber and metal are bonded by an adhesive agent coating several hundredths of a millimeter thick.

1 Cross-section of a torsional vibration damper of Winkelmann Powertrain

First step: Determination of the resolution of the gauge

Before analyzing the measuring device, it is necessary to check whether its resolution is sufficiently high for the analysis of the process to be measured. The measuring device must have a resolution better than 5% of the given tolerance window. This is the basis for determining measured values reliably.

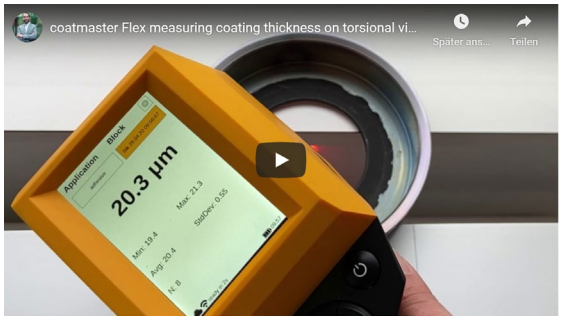
An adhesive agent coating with a specified layer thickness of 20µm ± 5µm is given as an example. With a tolerance of 10µm mm, 5% of the tolerance is equivalent to 0.5 µm. In this case this corresponds to a resolution of 0.5 µm over the entire measuring range.

Type-1 study: Accuracy and repeatability

The Type-1 study describes a method for determining the accuracy and repeatability of a measuring system. A reference with a known characteristic value (in our example the coating thickness) is used. The reference is measured at least 25 times and put back after each measurement. Based on the standard deviation of the measured values and the systematic measurement deviation, the cg value is then calculated.

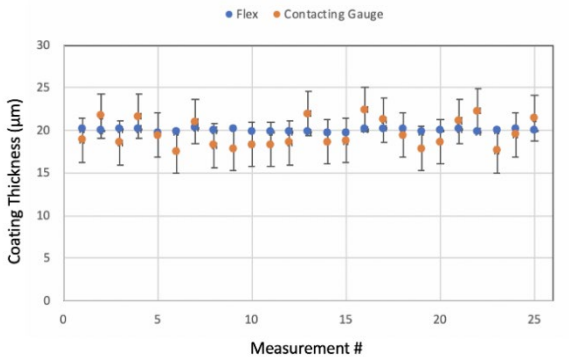
This method shall be illustrated by means of the non-contact coating thickness measurement with the coatmaster Flex (from the company coatmaster AG). The measuring system is based on Advanced Thermal Optics (ATO) technology, the pulse-like heating of the coating by a gas discharge lamp, and the measurement of the temperature response by a high-speed infrared detector. The evaluation of the measured data via physical model functions and the central storage of measured values is carried out in the coatmaster Cloud.

Video 1 shows the repetitive coating thickness measurement of the adhesion agent coating using the coatmaster Flex.



1 Video: Repetitive measurements using the coatmaster Flex on an adhesive agent coating on a flywheel of a torsional vibration damper. https://www.youtube.com/watch?v=zB7ZsbOlOc4

The coating thickness values from the measurement series with the coatmaster Flex are shown in figure 2 by blue measuring points. For comparison, a series of measurements were carried out with a contacting measuring probe (magnetic-inductive), shown with orange dots.



2 Repetitive measurement of the layer thickness of an adhesive agent coating with the coatmaster Flex (blue dots) and a contacting measuring device (orange dots).

The average values of both methods fluctuate around 20µm each. The standard deviations determined (corresponding to the error of a single measurement) with the coatmaster Flex and the tactile method are 0.18µm and 1.6µm respectively. With fixed positioning of the test object and the coatmaster Flex, the standard deviation even drops to below 0.05µm. This small standard deviation is due to the measuring method of the coatmaster Flex which averages the coating thickness on a circular area of 2mm. Remarkable is also the pronounced angle and distance independence of the measured coating thickness.

Suitability of the measuring method

For further evaluation of the suitability of the measurement procedure, the cg value is now determined from the two measurement series. This is calculated according to Bosch Heft number 10 using the following formula:

$$c_g = \frac{0,2 \times T}{6 \times s_g}$$

with the tolerance range T (upper tolerance limit minus lower tolerance limit) and the standard deviation sg. For quality control according to Bosch specifications, only test equipment with a cg value of more than 1.33 may be used.

With a tolerance range of 10µm, the coatmaster Flex has a cg-value of 1.9, making this measuring instrument suitable for process control of bonding agents on torsional vibration dampers. In contrast, the contacting probe is clearly unsuitable with a cg-value of 0.1 and must not be used.

Type-2 study, Gauge R&R study: Repeatability and reproducibility of the measuring instrument in use

Often only Type-1 study is used in the measurement system analysis. To investigate the repeatability and reproducibility of a measuring instrument in practical use, the much more elaborate method 2 is used. This method is only used after the measuring instrument has been classified as capable according to the Type-1 study. According to the Type-2 study, ten parts covering the entire scatter range of the measured feature are measured two or three times by three different operators (or at three different locations or with three different instruments of the same type). None of the operators can see the results of the other operators. The parts are measured in random order each time so that the operator cannot remember the measurement result of the previous time.

For each operator, a total average and an average span value (based on the differences between the largest and smallest measured value that the operator took for each part) is calculated. The difference between the largest and the smallest operator mean value allows a statement about reproducibility. The total average of the average span values calculated for each operator is used to make a statement about the repeatability. Based on repeatability and reproducibility, the total range of the measuring device is then calculated and related to the characteristic scatter or tolerance.

Conclusion

Type-1 study allows you to check the basic suitability of a gauge for monitoring your processes quickly and easily. The effort to carry out type-2 study in preparation as well as in execution is considerable but can be worthwhile just to protect against later liability claims. In many cases, inadmissible measuring devices are used for monitoring because the methods for measuring system analysis are not known or to avoid the effort of checking the measuring device. If I was able to take a first hurdle for the implementation of a measuring system analysis, this article has fulfilled its purpose.

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