Modern quality assurance of rubber-metal vulcanizations

The Winkelmann Group GmbH + Co. KG is a German group of companies headquartered in Ahlen in Westphalia with branch offices in Poland, Turkey and China. Nearly 4,000 employees currently generate sales of over half a billion Euro worldwide. The Winkelmann Powertrain Components GmbH & Co. KG as part of the Automotive division produces torsional vibration dampers for the automotive industry that are used in vehicles with internal combustion engines to reduce torsional vibrations.

Torsional vibrations are caused by the intermittent power transmission from the piston via the piston pin and the connecting rod to the crankshaft and create brief torque peaks. These peaks lead to noise and wear within the gears. Additionally, they stress the crankshaft, which might lead to torsional fractures. The purpose of a torsional vibration damper is thus the attenuation of these torsional vibrations.

The torsional vibration damper (see Figure 1) consists of two components, the inertia ring and the hub. The space between inertia ring and hub is filled with a rubber.

![Figure 1: Torsional vibration damper of Winkelmann Powertrain](image)

During the manufacturing process of torsional vibration dampers the surfaces of the inertia ring and hub in contact with rubber are sandblasted. Afterwards, these surfaces are coated with an adhesive. Through a subsequent vulcanization process a permanent connection of the inertia ring, rubber and hub is achieved.

The coating thickness of the adhesive is typically in the ten to twenty micrometer range with a tolerance in the range of only a few micrometers. If the coating thickness is below the tolerance range adhesion problems of the rubber - metal compound may occur. If the coating thickness is above the tolerance range cracks can occur in the adhesive layer under mechanical stress of the component. In both cases, the weakening of the adhesive layer causes failure of the torsional vibration damper during operation. The coating thickness measurement during the production process is therefore an important quality criterion to ensure the proper functioning of torsional vibration dampers.

For critical quality parameters the testing equipment has to be validated thoroughly.
For this purpose, the automotive industry introduced the capability parameter $c_g$. The $c_g$ value is calculated according to Bosch Heft No. 10 by means of 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 $s_g$ (corresponds to the error of a single measurement). Only test equipment with a $c_g$ value of above 1.33 may be used for quality control according to this standard.

In the past, eddy current or magneto-inductive measuring gauges were used to test the coating thickness of adhesives. On sandblasted and coated surfaces these gauges usually have a standard deviation of one or several microns (see Figure 3). In case of tolerance ranges of 20 microns this results in $c_g$ values of well below 1.33. These devices are therefore not capable for quality control.

"We were not satisfied with the results of the conventional coating thickness measurement methods. As part of the continuous improvement process, we were looking for an alternative and found the CoatMaster" says Harun Kelpet, industrial engineer responsible for operational quality assurance at the factory in Ahlen. "One of our employees, Mr. Gerste, submitted a suggestion for improvement and that is how we became aware of the Winterthur company."

Since October 2014 Winkelmann Powertrain uses the CoatMaster of Winterthur Instruments for quality assurance and thus, as a technological pioneer, fulfills the demanding requirements of the automotive industry.

The CoatMaster utilizes the method of thermal layer testing. The integrated light source heats up the surface of the adhesive for a few milliseconds by a few degrees. The dynamic surface temperature response is measured via optical elements and an infrared sensor. The technical data of the used light source are comparable to those of photographic flash tubes and do not present any potential risk to humans and the environment. The use of hazardous light sources such as laser, beta or X-ray emitters was deliberately avoided. To determine the coating thickness, on average 100,000 temperature values per measurement are analyzed within a fraction of a second. The measuring area is adjustable from 2 mm up to 50 mm from a distance of up to 1 m. The standard deviation can be reduced to significantly below 1 %, and measurement values can be recorded at a frequency of 1 Hz.
Figure 2: The CoatMaster Inline of Winterthur Instruments as typically used for thickness measurement in production lines.

The CoatMaster measures the thicknesses of adhesion promoters at a standard deviation of 70 nm (= 0.07 microns). This corresponds to a $c_g$ value of 4.5 at a tolerance window of 10 µm and thus meets the modern requirements of the automotive industry.

Figure 3: Comparison of the coating thickness measurement according to the classical magnetic induction method and the CoatMaster. The measurements were determined on a torsional vibration damper within an area of 5 mm diameter. The standard deviation of the magnetic induction method is 0.9 microns. This standard deviation corresponds with a tolerance window of 10 microns a $c_g$ value of 0.4. In the thermal layer testing as used by the
CoatMaster, the error of a single measurement is 0.07 microns, which corresponds to a $c_g$ value of 4.5. In contrast to previous measurement methods, the CoatMaster thus is capable to ensure that the production of the adhesive coating adheres to the tight tolerance requirements required for this application.

The precision and robustness of the CoatMaster enables our customers to implement quality standards as required by the automotive industry. Due to its compact size and non-contact measurement method, the CoatMaster is ideally suited for in-line production control. The real time measurement of the coating thickness allows reducing the consumption of bonding agent to a minimum, minimizing rejects and optimizing bonding quality of vulcanized parts.