Capability analysis of measuring systems for acceptance tests and reliable process qualification

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Abstract

The application of inline measuring and inspection systems for monitoring of the production processes is indispensable today in the wood-based composite industry. Beyond the display of results, there is an increasing integration of the measuring systems into process control and quality assurance. Process digitalisation and Industry 4.0 is already in progress in the branch. Here, reliable and evidently capable measuring systems and processes serve as basis to acquire numerous parameters. However, suitable methods for measuring system analysis are not prevalent in the wood industry. It is therefore commonplace that the results of measuring systems are often questioned without foundation or, on the other hand, their qualification is overestimated. Sometimes indices and parameters are used, which (shall) sound impressive but have no technical significance. Some technical terms are even misused. In addition, for some of the information in the data sheets it is unclear what they say about the capability of the measuring systems and how they are to be clearly proven. Furthermore, no agreed procedures for acceptance tests exist. Beyond the measuring systems, the total production process capability and performance is commonly qualified on the basis of a (too) small number of samples with tests on specimens from the lab-cuts. Here, the utilisation of inline measuring systems and their ability for comprehensive process qualification and acceptance tests is generally underestimated and not common practice so far.

Statistical methods in process management for capability and performance analysis are common practise in other branches such as the automotive industry and defined in international cross-industry guidelines and standards (VDA, VDMA, VDI, and ISO). The same applies to capability analysis of measuring systems as precondition of the process qualification. Here, e. g., VDA 5 and ISO 22514-7 define the most recent methods. However, their application in the wood industry appears non-trivial and requires respective adaptions to the special conditions of material and processes (cf. SOLBRIG et al. (2015), KORTÜM & RIEGEL (2017), ULLRICH (2018)). When evaluating inline measuring systems, corresponding references are often not available and questionably defined comparative measurements do not provide reliable results. Even the capability analysis of handheld and laboratory measuring devices is not common practice in the wood industry. Therefore, the guideline VDI 3415-2 (Woodworking machinery – Statistical methods) is currently being edited in order to provide suitable capability analyses methods considering both process and material conditions. Note, part one of the guideline VDI 3415-1 (Woodworking machinery – Process qualification of machine acceptance procedures) is already available and describes the procedure from the initial request to the final acceptance of the considered machinery equipment.

The fundamental approach of measuring system capability analysis is to evaluate the relation of measuring uncertainty and process variation (tolerance of the measured parameter). Here, the gauge capability index

$$c_{\mathrm{g}} = \frac{n\% \cdot T}{2 \cdot u \cdot s_{\mathrm{g}}}$$

is a common figure with a multiple of the standard deviation s_g for the gauge uncertainty (quantiles of the Gaussian distribution) as a fraction of the percentage process or property tolerance T as difference of upper and lower specification limits. Today, the quality indices Q following ISO 22514-7 become more important. However, the approach is similar. Here, the measuring system capability ratio is calculated via

$$Q_{\mathrm{MS}} = \frac{2 \cdot U_{\mathrm{MS}}}{T} \cdot 100\ [\%]$$

with the uncertainty of the measuring system $U_{\mathrm{MS}} = k \cdot u_{\mathrm{MS}}$ as a multiple of the combined standard uncertainty of the measuring system u_{MS} with the coverage factor k representing the selected confidence interval. If the measuring uncertainty u_{MS} cannot be directly determined by means of, e. g., repeat measurements it can also be estimated via

$$u_{\mathrm{MS}} = \sqrt{\sum u_{\mathrm{MS}_i}^2}$$

as sum of the identified single uncertainties u_{MS_i} with influence on the measuring application (propagation of uncertainties as sum of the variances). The same procedure applies to the determination of the measuring process capability ratio

$$Q_{\mathrm{MP}} = \frac{2 \cdot U_{\mathrm{MP}}}{T} \cdot 100\ [\%]$$

where further influence parameters come in addition, which may increase the uncertainty of the measuring process U_{MP}. Finally, the calculated indices or ratios are compared to respective reference values in order to qualify the measuring system or process.

However, inline measuring and inspection systems require further considerations. In panel production, the measuring devices must be suited to the individual requirements of the versatile measuring tasks, the type of product, and the position in the process. The same applies to the respective performance test procedures for the individual systems. Therefore, practice-oriented procedures have been developed for capability analysis of inline measuring systems based on statistical methods, which are available to the customers as Standard Operating Procedures (SOPs) complete with the correspondingly defined tolerances. Furthermore, the developed methods serve as agreed procedures for acceptance tests. To this end, suitable approaches from existing standards and guidelines have been adapted to the special conditions in wood-based panel production. With respect to the measuring technology and the influence parameters on the measuring process, clear technical specifications are defined. With further consideration of panel product and process conditions, individual guarantee values are specified. For acceptance tests, reasonable comparison tolerances are calculated considering the uncertainties of both the measuring process as well as the respective reference method.

Examples for capability analyses of measuring systems for acceptance tests and their benefit for reliable process qualification are shown regarding measuring and inspection systems in the forming line as well as after the hot-press. Ultimately, the user receives an instrument for evaluating existing and assessing new equipment. The use of such qualification methods enables the European wood-based panel industry to set standards in this field.

Literature

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