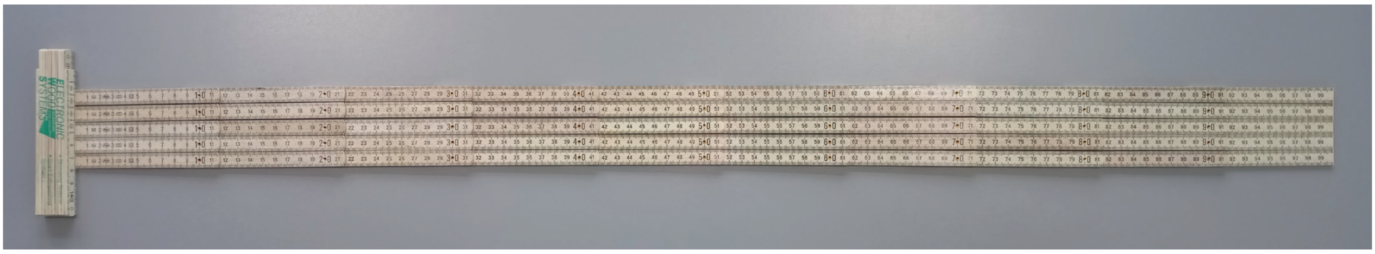
WHAT REALLY COUNTS

Despite the global coronavirus crisis, opportunities in the realms of methods for capability analysis of inline measuring and inspection systems exist in the wood-based composite industry, says Hauke Kleinschmidt general manager of Electronic Wood Systems, Germany (EWS)



Above: *Figure 1: Even comparable measuring devices do not provide identical results – varying lengths of customary metersticks with +/- 1 mm tolerance acc. to the accuracy class.*

One thing we learned in coping with the ongoing Covid-19 pandemic is what really counts in such demanding times. Capability, reliability, flexibility, availability, and effectiveness matter not only for business partners but also regarding the applied technologies.

Business changed as a consequence of restrictions throughout 2020 and resulted in many fewer sales and service trips. Thanks to video conferences, contact with customers could be maintained without any problems.

It is positive that customers also use the new communication options and are not afraid of discussions in front of the web-camera. Product presentations, technical or commercial discussions, but also training and support for the commissioning of systems via the internet will be far more a part of EWS in the future than it was in the past.

The option of sharing content during video conferences enables flexible home office concepts to be extended with the target to increase the employee's satisfaction at the same time as keeping up the contact to customers and suppliers.

Despite the pandemic, EWS continues to pursue innovative developments of measuring as well as spark extinguishing systems and works out interesting strategies for maintenance management in order to minimise the downtimes of the production line. Preventative maintenance is becoming an increasingly important topic to ensure that the measuring and spark extinguishing systems are available around the clock with the highest level of capability and reliability for the production of wood-based panels between planned maintenance shutdowns of the production line.

Beyond R&D and service concepts, EWS's head of technology wood-based composites Konrad Solbrig is busy with developing reasonable and practice-oriented evaluation methods to individually prove the capability of the inline measuring and inspection systems. The capability analyses are furthermore intended to serve as agreed procedures, for site acceptance tests, for example.

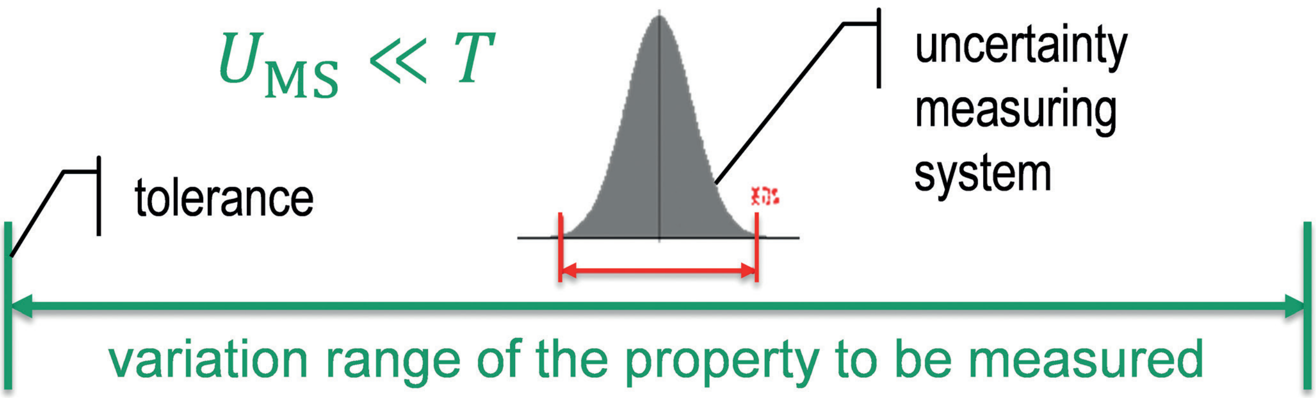
The following article is based on his presentation planned for the cancelled EPF Symposium 2020. Some aspects may appear obvious but often cause misunderstandings in practice, thus there is some need for clarification.

QUALIFICATION METHODS

The application of inline measuring and inspection systems for monitoring production processes is indispensable in today's wood-based composite industry. Beyond the display of results, there is an increasing integration of the measuring systems into process control and quality assurance. Here, reliable measuring systems and processes, with proven capability, serve as the basis to acquire numerous parameters.

However, suitable methods for measuring system analysis are not very common in the wood industry. It is therefore commonplace that the results of measuring systems are questioned without foundation or, on the other hand, their qualification is over-estimated. Furthermore, there are no agreed procedures for acceptance tests. 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 to carry out comprehensive process qualification and acceptance tests, is generally under-estimated and is not currently common practice.

Statistical methods in process management for capability and performance analysis are common practice in other branches, such as the automotive industry, and defined in international cross-industry guidelines and standards (AIAG, VDA, VDMA, VDI, and ISO). The same applies to the capability analysis of measuring systems as a pre-condition of the process qualification. Here, for example, VDA 5 and ISO 22514-7 define the most recent methods. However, their application in the wood industry is not straightforward and requires adaptations to the special conditions of materials and processes. 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 hand-held 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 created in order to provide suitable capability analysis



Above: *Figure 2: Capability analysis of a measuring system or process (with the indices Q_{MS} or Q_{MP}) by means of the ratio of measuring uncertainty and tolerance of the property to be measured.*

methods that consider both process and material conditions. Note, this German guideline is to be published in both German and English.

FUNDAMENTALS

The fundamental approach of measuring system capability analysis is to evaluate the relationship of measuring uncertainty and variation (tolerance) in the parameter to be measured *(Figure 2)*. To this end, average and standard deviation of the measuring system is determined by means of repeat measurements (typically 50, but at least 25) on a reference, or comparison, standard. On that basis, the gauge capability index

$$C_g = \frac{n\% \cdot T}{2 \cdot u \cdot s_g}$$

can be calculated and this used to be common practice, with a multiple of the standard deviation s_g for the gauge uncertainty (quantiles of the Gaussian distribution). It is expressed as a fraction of the percentage process or property tolerance T, as the difference between upper and lower specification limits. Today, the quality indices Q, following ISO 22514-7 are the more important figures. However, the approach is similar. Here, the measuring system (MS) capability ratio is calculated via

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

with the uncertainty of the measuring system calculated with

$$U_{MS} = k \cdot u_{MS}$$

as a multiple of the combined standard uncertainty of the measuring system u_{MS}, with the coverage factor k representing the selected confidence interval (e. g. k=2≙95,45 %). If the measuring uncertainty u_{MS} cannot be directly determined by means of, for example, repeat measurements, it can also be estimated via

$$U_{MS} = \sqrt{\Sigma u_{MSi}^2}$$

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

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

where further additional influence parameters come in. These may typically increase the uncertainty of the measuring process U_{MP}.

The evaluation of the capability of measuring systems and processes by means of statistical methods considers the potential influence of systematic and random factors on the measuring results.

Finally, the calculated indices, or ratios, are compared to their respective reference values in order to qualify the measuring system or process. For common practice, ISO 22514-7 and other standards recommend a limit of Q_{MS}≤15 %. For applications in the wood industry, an increment to Q_{MS}≤20 % appears reasonable with respect to the special conditions. Since various parameters influence the measuring process, the limit typically increases to Q_{MS}≤30 % and even further for the individual measuring processes on wood and wood-based composites.

INLINE SYSTEMS REQUIREMENTS

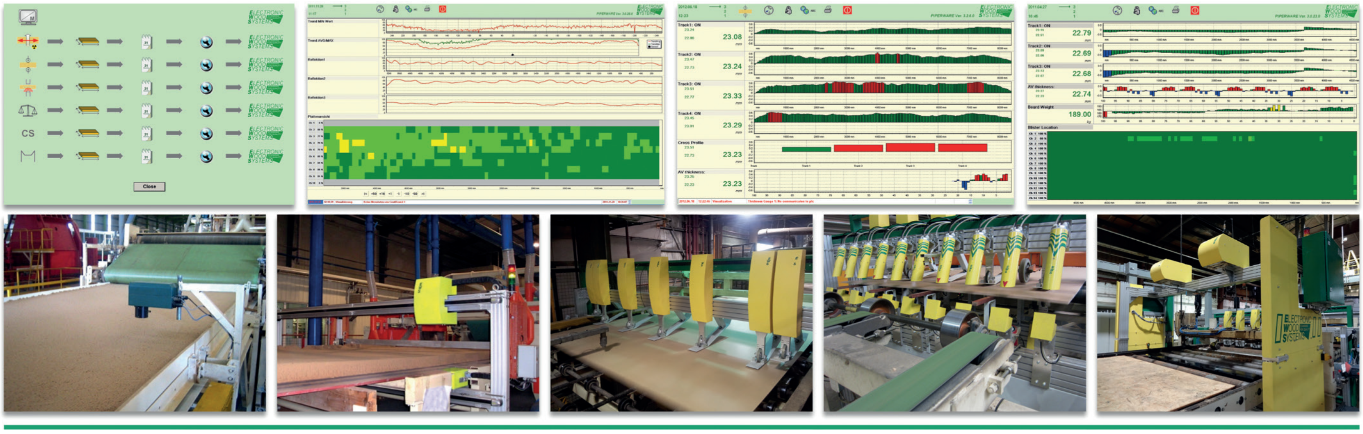
Obviously, inline measuring and inspection systems require further consideration: Like the devices themselves, the performance test procedures must be suited to the versatile measuring tasks and conditions. Therefore, practice-oriented procedures have been developed by EWS for capability analysis of inline measuring and inspection systems, based on statistical methods and suitable approaches from existing standards and guidelines. There are three main issues to be explicitly considered for capability analyses in wood-based panel production, ie

- sampling from the process,
- reference standards or measurements, and
- comparison tolerances.

Well-defined procedures take the individual conditions at each position of measuring and inspection systems along the production line *(Figure 4)* into account. Furthermore, one must distinguish between the inherent performance of the system itself (Q_{MS}) and its application in the process under production conditions (Q_{MP}), where both aspects required respective procedures. Regarding the latter, however, inappropriate operation may not be attributed to the devices.

An easily comprehensible example for

Above: *Figure 3: Thickness measurement and ceramic gauge blocks*



Above: *Figure 4: Inline measuring and inspection systems with individual requirements depending on the versatile conditions of the position in the production line*

variable parameters is the thickness gauge for measurements on panels after the diagonal saws, or in the sanding line. The resolution is mainly specified by the internal position sensors according to the sub-supplier's data sheet – no matter how many digits are displayed.

However, there is more to it than just resolution. The inherent accuracy and precision of a thickness measuring system in static conditions is analysed by means of repeat measurements on ceramic gauge blocks *(Figure 3)* as the final manufacturing check or site acceptance test. This requires downtime and access to the line.

On the contrary, the thickness measuring system capability analysis under production is carried out by lab-cut sampling (at least n = 5) and track-identical comparison measurements with a suitable hand-held measuring instrument (eg external micrometre with separate proof of capability).

For the comparison of inline and reference measurements, individual tolerance calculation takes the random and systematic methodical influences – as well as thickness shrinkage of the hot panel on the way to the lab – into account. According to the agreement, 95% of the values must be within the comparison tolerance. Likewise, the measuring process of X-ray panel scales is analysed by track-wise comparison towards the corresponding density values from the lab-cuts.

In the forming process, reliable sampling from the continuous mat is not possible. Here, it has been tried and tested to perform the capability analysis of traversing X-ray area weight measuring systems preferably via gravimetric reference measurements of the cross profile on panel lab cuts. This must take into consideration variation of the moisture distribution and knowledge of the lateral mat expansion in the hot press. Furthermore, this procedure allows checks during production on a regular basis without the need for downtime and special equipment. Again, practice-oriented comparison tolerances are calculated by statistical methods considering the individual conditions.

On the other hand, the performance evaluation of inspection systems for attributive parameters such as X-ray foreign body detection in the mat forming, or ultrasonic blow detection in the panel, appears more straightforward. The procedure can be roughly summarised by saying that all agreed foreign bodies, defects or delaminations, must be detected at the corresponding settings and production conditions (mainly line speed). Pre-defined test specimens of metal or non-metal foreign bodies are randomly positioned on the mat upstream of the scanner.

Defects for blow detection are simulated by means of cardboard pieces on the panel surface, which interfere with the ultrasonic signal in a similar way to a real delamination inside the panel. For both foreign body and blow detection, distinction must be made between minimum possible and guaranteed detectable defect sizes.

AGREED PROCEDURES

Beyond the aforementioned examples, comprehensive and precise descriptions for all inline measuring and inspection systems will be available to customers as Standard Operating Procedures (SOPs). For acceptance tests, reasonable comparison tolerances and individual guarantee values are calculated, taking into consideration the uncertainties of both the measuring process and the respective reference method, as well as relevant influence parameters from the process and material.

Ultimately, the user receives an instrument for evaluating existing, and assessing new, equipment. Thus, standardised procedures and indices enable an equivalent, reasonable and fair comparison for all parties involved. Such measuring and inspection systems with proven capability are well-suited for reliable production process qualification. Further integration into intelligent process automation, with superior control technology, such as Prod-IQ Next by Siempelkamp, allows the continuous optimisation of wood-based panel production. ●

Above: *EWS inline blow measuring*