Can Artificial Intelligence Replace Classical Testing of Corrugated Board?

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For many years, laboratory testing has been the cornerstone of quality evaluation in the paper and corrugated board industry, supporting both material control and packaging design. However, growing production complexity and the need for faster technological decisions expose the limitations of traditional, time-intensive testing methods. This editorial explores the potential of artificial intelligence as a tool that can complement, rather than replace, classical approaches. Machine learning models are capable of estimating key strength parameters such as ECT and BCT, identifying anomalies, and supporting material selection based on process and environmental data. Nevertheless, their effectiveness depends strongly on data quality, and they cannot substitute for standardized tests required for validation and certification. It is argued that the most effective path forward is a hybrid model, combining the reliability of laboratory testing with the speed and predictive power of AI, leading to more efficient and informed decision-making.

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Introduction

For decades, laboratory testing has been the backbone of the paper and corrugated board industry. Tests such as the edge crush test (ECT), box compression test (BCT), short-span compression test (SCT), and ring crush test (RCT), together with grammage and moisture measurements, have enabled reliable material assessment and safe packaging design (Biancolini and Brutti 2003; Garbowski 2025). However, the industrial environment is changing. Production is becoming more dynamic, product variability is increasing, and decisions must be made faster. In this context, the laboratory is not only a guarantor of quality, but also a potential bottleneck. This creates space for artificial intelligence.

From Testing to Prediction

Artificial intelligence in the paper industry is primarily a tool for analyzing data and predicting outcomes. Modern production systems generate large datasets describing materials, processes, environmental conditions, and product performance. These data enable the development of machine learning models capable of estimating key parameters such as ECT and BCT before testing is completed (Gajewski *et al.* 2024; Garbowski 2024). This represents a shift from reactive to proactive quality control. Instead of evaluating results after production, decisions can increasingly be supported during the process.

The Role of Data and the Laboratory

The effectiveness of AI depends on data integration: material properties, process parameters, geometry, environmental conditions, and historical laboratory results. In this system, the laboratory remains essential. It provides reliable reference data and serves as the foundation for model training (Garbowski 2024). Thus, the laboratory does not disappear. It evolves from a purely testing unit into a source of structured knowledge supporting predictive systems.

What AI Can Already Do

Artificial intelligence is already capable of supporting several practical tasks. Prediction of ECT and BCT parameters is one of the most advanced applications, and this is supported by both experimental and numerical research on corrugated board behavior (Gajewski *et al.* 2024). AI can also detect quality anomalies by identifying patterns in process data that precede material degradation. Another important area is material optimization, where models suggest combinations of liners and fluting that meet requirements at reduced cost. In addition, real-time monitoring systems based on sensors and computer vision extend quality control directly to the production line.

Limitations of Artificial Intelligence

Despite its potential, AI has clear limitations. Its effectiveness depends on data availability and quality. For new materials, novel structures, or rare failure scenarios, predictions may be unreliable. Classical laboratory testing remains necessary for certification, compliance, and validation of new solutions. A model prediction cannot replace a standardized test result. Another limitation is interpretability. Many models provide accurate predictions but limited insight into underlying mechanisms. In practice, understanding causes is often as important as predicting outcomes.

Human expertise also remains essential. Technologists interpret results within a broader process context, including supplier changes, environmental conditions, and operational factors (Cornaggia *et al.* 2023). AI complements this knowledge but does not replace it (Di Russo *et al.* 2024).

The most realistic development scenario is a hybrid system combining artificial intelligence and classical testing (Garbowski 2024). The laboratory provides validation and reference data, while AI enables fast prediction and early warning. Routine testing can be reduced, and laboratory resources can be focused on critical cases. This approach also changes the role of specialists, shifting their work from repetitive testing toward analysis and decision support.

Implementation Challenges

The main barriers to implementation are organizational rather than technological. Data quality and consistency are often insufficient. Production, laboratory, and operational data are frequently stored in separate systems, making integration difficult. There is also the issue of trust in model predictions and the need for interdisciplinary competencies. In addition, models require continuous updating as materials and processes evolve.

Readiness for AI adoption varies. Large companies with advanced data systems are best positioned, while smaller organizations may need to first improve data management. Nevertheless, increasing market pressure for efficiency, quality, and sustainability is driving interest in AI-based solutions.

Conclusions

Artificial intelligence can already support prediction of key parameters, detection of anomalies, and optimization of materials (Gajewski *et al.* 2024; Garbowski 2024). In routine applications, it can significantly accelerate decision-making and reduce testing effort. At the same time, classical laboratory testing remains indispensable for validation and compliance (Biancolini and Brutti 2003; Di Russo *et al.* 2024). The future lies in integration rather than replacement. Artificial intelligence will not eliminate the laboratory, but it will redefine its role. The laboratory measures the present. Artificial intelligence anticipates the future. Only together can they provide a complete picture of material behavior.

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