

An innovative portable laser profilometer for the measurement of Gap and Flush in Automotive

As automotive manufacturing evolves, achieving zero-defect quality in the final assembly is a top priority. One critical area is the control of gap and flush between body panels, doors, and trims — essential not just for aesthetics but also for aerodynamics, noise reduction, and customer satisfaction.

This paper outlines how a Human-Centric Manufacturing (HCM) approach, empowered by the use of an innovative portable laser profilometer named G3F developed by U-SENSE.IT srl (www.u-sense.it), can ensure precise and efficient measurement of gap and flush, enabling zero-defect assembly in the automotive industry. The G3F is one of the Non Destructive Inspection systems developed in the openZDM project for the Volkswagen Autoeuropa use case.

Human-Centric Manufacturing Overview

Human-Centric Manufacturing is a strategy that keeps the operator at the center of the production process, supported by smart tools and digital technologies. It emphasizes:

- Ergonomics and usability of tools
- Skill enhancement and decision-making capabilities of the operator
- Real-time data acquisition to support quality control

Rather than removing the human element, HCM enhances it with intelligent assistance – especially valuable in the final vehicle assembly, where precision and variability coexist that implies the need of manual operations limiting the use of automation.

Among the operations performed by the operators in the final assembly of a car production line, there is the verification of the gap and flush among parts of the cars.

- Gap: The space between two adjacent panels (e.g., door and fender)
- Flush: The height difference between the surfaces of two adjacent panels

These measurements are crucial in the final stages of car manufacturing, where cosmetic and functional integrity must meet strict quality standards. Currently, in the majority of the cases, mechanical gauges are used by operators, allowing a fast verification, without the possibility of saving the data for further analysis and correlation. In the era of Industry 4.0 this is a limitation as the availability of data is mandatory to achieve higher quality aiming at Zero Defect Manufacturing.

For this reason, an innovative laser profilometer has been introduced that implements disruptive strategies for the measurement of the gap and flush in the final assembly of car body, such as:

a) smartness, thanks to Artificial intelligence algorithms to control measurement uncertainty, by compensating operator deficiencies in handling the device, maximizing image quality on optically different surfaces through semantic segmentation and tuning interventions (realignment, measurements) at certain stages depending on the data measured at previous stage;

b) ergonomics and intuitive interface, through component miniaturization and edge computing, lightweight, battery-powered, with an immediate interface, allowing single hand use and pocket size, essential features for an effective uptake and competitors' differentiation;

The G3F (see picture below) has been fully integrated in the IT infrastructure of the plant through the openZDM platform, allowing the complete traceability of the acquired data by the operators.



During the validation carried out in the Volkswagen Autoeuropa assembly lines, several are the benefits observed, like:

- Increased Accuracy: Sub-millimeter measurement capability ensures precise alignment and panel fit.
- Real-Time Feedback: Defects are caught and addressed immediately, preventing rework further downstream.

- **Flexibility:** Operators can inspect multiple car models or variations on the same line without the need for fixed inspection stations.
- **Operator Empowerment:** Workers are equipped with advanced tools, increasing their engagement and ownership of quality.
- **Data-Driven Improvement:** Recorded data helps identify trends and root causes, feeding back into design or process optimization.

Conclusions

The proposed portable laser profilometer for gap and flush inspection tested in the car final assembly line combines the judgment and adaptability of skilled operators with the precision and consistency of digital tools, ensuring that every vehicle leaves the line with zero visible defects and maximum customer satisfaction. Moreover, the full integration of the portable device with the openZDM platform guarantees the complete fulfilment of the Industry 4.0 standards.

Therefore, the use of advanced Non Destructive inspection systems, like the one proposed for the Volkswagen Autoeuropa use case, not only boosts quality but also promotes a culture of continuous improvement and operator empowerment, making it a strategic win in the journey toward zero-defect manufacturing.