Wearable Devices Enhancing Human Capabilities In Direct Enamel Painting Defect Detection

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The external surface of a vehicle plays a pivotal role in shaping the perception of its quality, influencing customer purchase decisions, impacting brand image, and determining repeat business (Wedowski et al., 2012; Baudet et al., 2013). The significance of maintaining a flawless exterior extends beyond immediate customer satisfaction, as it safeguards the manufacturer's brand reputation and ensures long-term profitability. Despite wadvancements in technology, visual inspection remains a crucial aspect of quality control, particularly in cases involving complex or unpredictable defects (Wedowski et al., 2012; Baudet et al., 2013). Human inspectors are adept at discerning nuanced imperfections that may elude automated systems. However, this reliance on manual inspection introduces challenges such as eye fatigue and discomfort (Wilhelm et al., 2011), which can compromise the accuracy and efficiency of the process and eye health.

The study proposes an integrated approach that combines human inspection with innovative technologies to improve the examination of external surface enamel painting on vehicles. It acknowledges limitations of visual inspection, especially regarding human factors, and aims to optimize accuracy and efficiency while minimizing eye fatigue. The proposed detection method involves a detailed process description, where a designated individual examines defects. Three critical aspects are considered: the environmental impact on the detection process, human factors, and method validation.

The environmental aspect, in this context, centers on the lighting system recognizing that suboptimal conditions like excessive illuminance and glare contribute to eye fatigue and reduced defect detectability (Sanders and McCormick, 1995). To mitigate these challenges, a portable inspection LED device is introduced, strategically designed to optimize the lighting conditions for defect detection (Tjolleng et al., 2023). Excessive illuminance is addressed through the projection of light-dark stripes at an optimal 500 lux (Tjolleng et al., 2023), significantly reducing eye discomfort and fatigue. The anti-reflective feature ensures clear vision without disruptive reflections, and the incorporation of efficiency stripes using LED technology creates a balanced play of light and shadow. The device's compact and lightweight design facilitates easy handling during inspections. The previously mentioned intervention employs diffuse reflection (Kumar and Choudhury, 2014). The diffused lights worked on the following principle (Sylvain, 2005): incoming light rays from the lighting device were reflected on the appropriate surface in well-defined directions (regular reflection); see Figure 1 (a). In contrast, incident light rays were scattered in irregular directions (diffused reflection) across the atypical surface (with defects); see Figure 1 (b).

The examination of the human element and methodology involves a detailed analysis of how individuals perceive, evaluate, and respond to defects, focusing on variations in performance among operators. The eye-tracking system Tobii Pro 3 is introduced as a valuable tool for addressing judgment precision and effective corrective actions (Zheng et al., 2022). The device also measures visual fatigue, allowing a deeper analysis of operators' eye health, revealing characteristics like prolonged focus, eye movement patterns, and strain indicators. This comprehensive approach is crucial for improving operator performance.

Approximately 15 operators exclusively stationed at this workstation will participate in the case study, where the emphasis lies on caution regarding flakes and drops of enamel during detailed inspections of the hood and side flanges of the vehicles. The proposed methodology involves using an LED device and conventional methods to compare results and select the optimal lighting solution. The Tobii Pro system collects eye data to understand visual behavior during inspections. Following the trials, participants will be asked to rate their perceived mental, physical, and temporal demands, as well as their performance, effort, and annoyance, using the Raw Task Load Index (RTLX) (Hart, 2006). Other questionnaires will collect self-evaluation of satisfaction, comfort, and visual tiredness. The data will be analyzed to validate the suggested model in defect detectability and operator health.

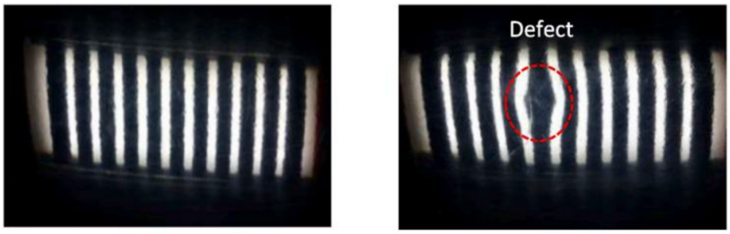

Fig. 1. (a) acceptable surface; (b) abnormal surface. Image from (Tjolleng et al., 2023).

In summary, this study introduces a new method for detecting defects in enamel external surfaces on vehicles, combining technological advancements with human insights, aiming to enhance defect detection accuracy and operator well-being.

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