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SIMULATION STUDY WITH NEW PAINTING TECHNOLOGIES: INK-JET PRINTING & UV CURING AND PAINTED FILM VACUUM FORMING

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ABSTRACT

Traditional automotive painting, such as spray painting with oven drying, faces scalability challenges, high energy use, and significant environmental impacts. Emerging alternatives include ink-jet printing with UV curing and painted-film vacuum forming. To fully capitalize on these advanced technologies, feasibility assessments through advanced simulation and optimization techniques are essential at the design stage of manufacturing systems. This study focuses on two processes: (1) the ink-jet printing & UV light curing-based painting process and (2) the painted film vacuum forming painting process. We aim to identify potential operational issues and propose corresponding solutions to ultimately achieve desired throughputs. It is expected that the considerations presented regarding production operations for adopting advanced painting technologies will serve as a useful reference for practitioners in the automotive painting area.

1 INTRODUCTION

The traditional automotive painting method faces challenges such as limited scalability, high energy consumption, and considerable environmental impact. Innovative alternatives like ink-jet printing & UV light curing, and painted film vacuum forming have emerged (Scotton et al. 2021; Takenouchi et al. 2013). Ink-jet printing & UV light curing enables precise, waste-minimizing application of ink to designated areas and reduces drying time by eliminating high-temperature thermal treatment. Painted film vacuum forming, a dry painting method unlike chemical-based wet processes, offers highly uniform finishes with excellent quality and consistency. To capitalize on these technologies, we developed simulation models replicating the entire painting process to optimize layouts and flows. Simulation-based optimization was employed to refine the layout, ensuring that the process meets throughput targets while minimizing costs. The focus of this study is on the empirical validation and practical implementation of new painting processes, through simulation-based identification and resolution of potential operational issues.

2 NEW PAINTING TECHNOLOGY-BASED PAINTING PROCESS

Figure 1 illustrates the process flow of both conventional and new painting processes. The energy- and resource-intensive spray painting process, which involves high-temperature curing, masking, and paint waste, leading to environmental impact and limited flexibility. The ink-jet printing and UV light curing

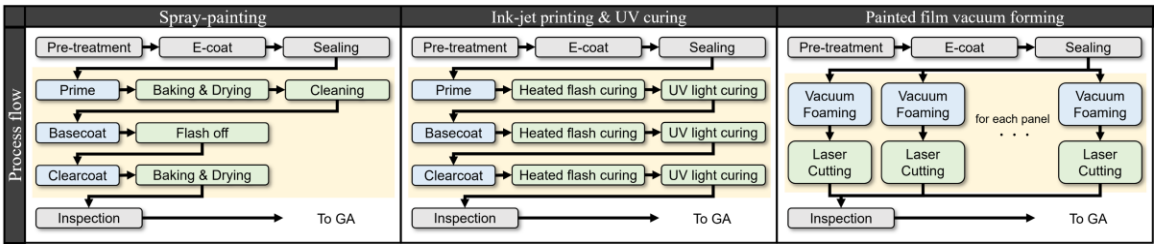

Figure 1: Production flow in the automotive painting process.

technology is a non-contact painting method that utilizes UV-curable ink, which solidifies immediately upon exposure to UV light (Scotton et al. 2021). A key difference is the curing process: spray painting uses thermal baking, while ink-jet uses heated flashing and UV exposure. Painted film vacuum forming is a painting technology in which a pre-painted film is heated in a sealed environment, adhered to the panel surface, and securely bonded through vacuum pressure (Takenouchi et al. 2013). This process involves vacuum film forming and laser trimming, while omitting both thermal treatment and the multi-layer coating.

3 SIMULATION STUDY

Two simulation models were built for (1) an ink-jet printing & UV light curing-based painting process, and (2) a paint film vacuum forming painting process. Figure 2 shows the identified problems and corresponding solutions. Initially, both layouts were unable to meet the throughput targets. The target Job Per Hour (JPH) for the ink-jet printing & UV light curing-based painting process was 11 JPH, while the target JPH for the paint film vacuum forming painting process was 6 JPH. However, through the application of simulation-based optimization techniques, we were able to refine the process layouts and configurations, achieving the productivity goal with a 51.2% improvement in JPH compared to the prior scenario.

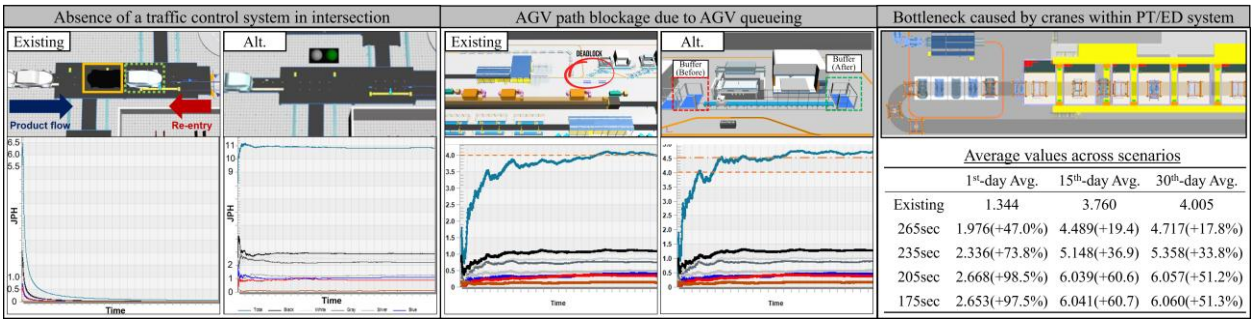

Figure 2: Identified problems and solution proposed utilizing simulation.

4 CONCLUSIONS

Introducing innovative alternative technologies to replace traditional painting processes in the automotive industry is essential for ensuring feasibility and sustainability. Two simulation models were built for (1) an ink-jet printing & UV light curing-based painting process, and (2) a paint film vacuum forming painting process. This study successfully demonstrates the effectiveness of using simulation-based optimization to enhance these processes. The optimized layouts provide a feasible and sustainable alternative to traditional methods, with a clear pathway for practical implementation in automotive manufacturing. Future research should examine the feasibility of developing scalable manufacturing systems based on these painting processes and investigate the trade-off between cost and flexibility.

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