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Ultra-High-Efficiency Production Technology for Mass Production of 2nd-Generation Fuel Cell Systems

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For the widespread adoption of fuel cell systems, manufacturing technologies capable of achieving highly stable quality, cost competitiveness per unit, and stable supply capability are indispensable. However, the production of fuel cell stacks and modules involves several challenges for mass production, including the use of expensive materials such as catalysts, electrolyte membranes, and diffusion layers, the high-precision assembly of thin and easily deformable components, quality assurance through inspection across multiple processes, and the construction of manufacturing systems requiring large-scale equipment investment. In particular, in the early generations, many processes relied heavily on manual transport, alignment, stacking, and inspection, which imposed major constraints on productivity, quality stability, and investment efficiency.

This paper reviews the evolution of production technologies for fuel cell stacks and modules from the 09 Model-Generation to the 2nd-Generation from the viewpoints of material utilization, labor efficiency, and investment efficiency. For material utilization improvement, structural and process evolutions were pursued not only to use expensive materials efficiently in power-generating areas, but also to promote the use of general materials in non-power-generating areas, reduce trimming loss during processing, and improve yield. For labor efficiency improvement, process integration in coordination with product specifications, cycle-time equalization among processes, and the establishment of an integrated fully automated production line were pursued. To achieve this, technologies were developed and applied for picking and placing thin rectangular materials that are prone to wrinkling and distortion, high-precision positioning, in-line dimensional inspection, and cell stacking assembly. For investment efficiency improvement, equipment integration and higher production speed were pursued to reduce equipment burden while maintaining the required production capacity. In the coating process, common use of coating equipment was also achieved by enabling the coating of different functional layers with the same coating machine.

In the 2nd-Generation, these elemental technologies were not limited to improvements in individual processes, but were integrated into a high-throughput production system connecting material input, electrode formation, membrane electrode assembly, cell stacking, stack assembly, module assembly, and inspections. In addition, in the actual mass-production environment, continuous improvements were carried out to address issues that are difficult to identify during development, such as equipment maintenance, lot-to-lot material variation, foreign material contamination, instability in supply systems, and the difficulty of inspection judgment. These efforts included optimization of process conditions, equipment improvements, automation of quality assurance, and yield improvement through data utilization.

As a result, from the 1st-Generation to the 2nd-Generation, material utilization improved by 25%, labor efficiency improved by 15 times, and investment efficiency improved by 4 times. Accordingly, the human-dependent manufacturing process that had been built up from the 09 Model-Generation through the 1st-Generation evolved in the 2nd-Generation into a high-throughput production system supporting the widespread use of fuel cell systems as industrial products. The knowledge obtained through this development provides a manufacturing foundation for the further spread of fuel cell systems and also contributes to future next-generation fuel cell production technologies.

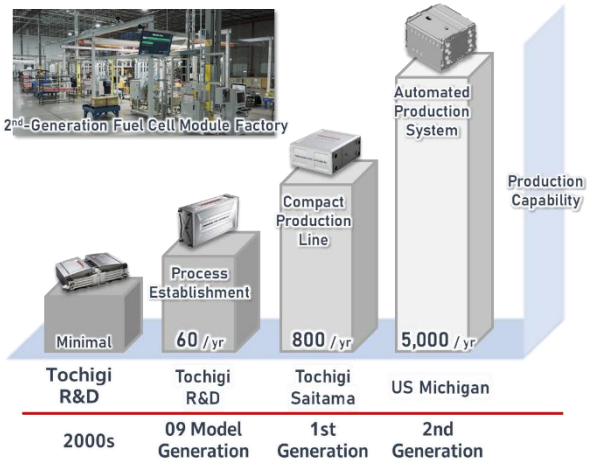

Fig.1 History of Fuel Cell Production Capability

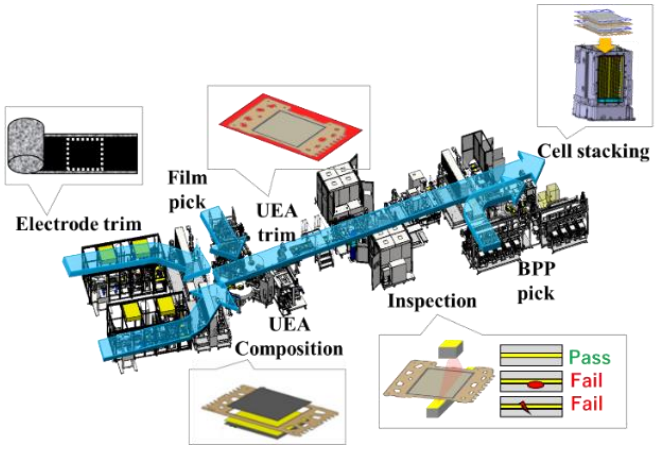

Fig.2 Overview of Fuel Cell Stack production system